The Rigging and Gun Tackle Blocks of the Swedish Royal Warship *Vasa*

By Nathaniel Frantz Howe

November 2011

Abstract

Rigging blocks are absolutely essential to the operation of a large sailing vessel, yet little has been published on these vital pieces of hardware. This thesis examines and analyzes the rigging and gun tackle blocks found in association with the Swedish royal warship, *Vasa,* lost in Stockholm Harbor on its maiden voyage on 10 August 1628. It explores the typology, nomenclature, historical development, and the physical mechanics of block technology and its application aboard square-rigged ships from antiquity to the 17^{th} century. *Vasa*'s blocks are discussed in detail, focusing on form, distribution at the wreck site, and interpretations of certain identifiable groups of blocks and a suggested reconstruction of the use and placement of these blocks in the rig. The final section compares *Vasa*'s rigging and gun tackle blocks to other archaeological examples from the period and draws conclusions regarding the patterns of block design, manufacturing methods, and national rigging practices. This archaeological information is then combined with the limited historical sources available to deduce the nature of the working environment of the navy yard blockmaker and the broader social organization behind the production and usage of this vital hardware both onboard *Vasa* and in the navy yard.

Rigging and Gun Tackle Blocks of the Swedish Royal Warship *Vasa*

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In Partial Fulfillment
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By
Nathaniel Frantz Howe

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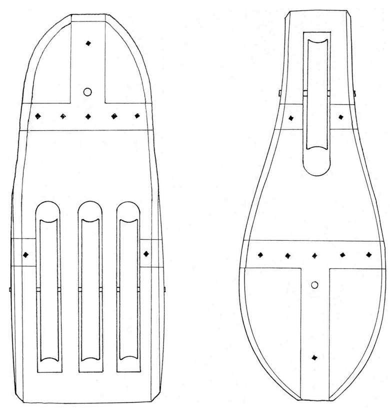

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Dedicated to the memory of my friend and mentor,

Ole Magnus

1948-2009

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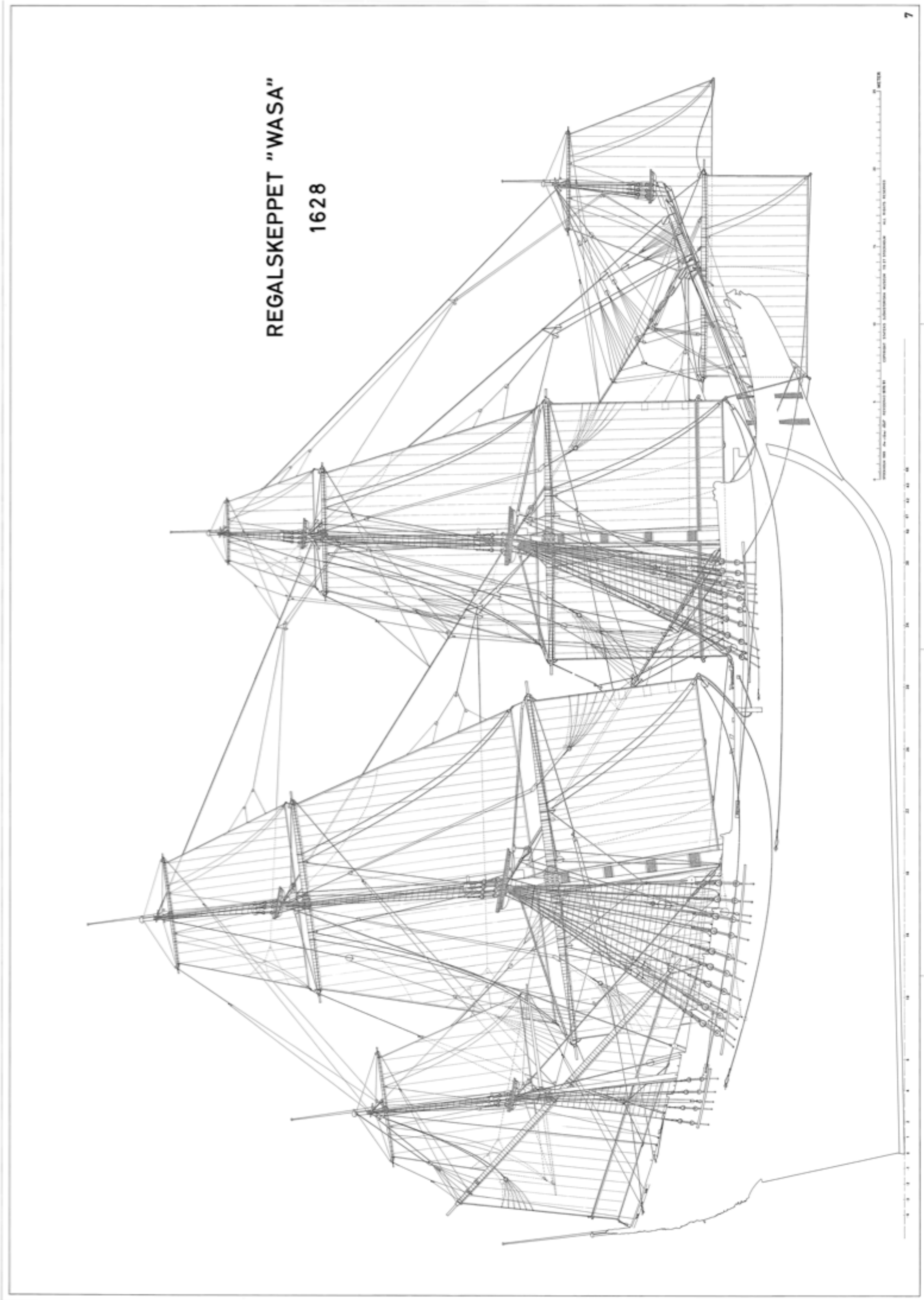


FIGURE i.1. Reconstruction of *Vasa*'s rig by Eva Marie Stolt, 1988. Updated by Dr. Fred Hocker, 2006 (Courtesy of the Vasa Museum).

Chapter 1. Introduction to Blocks

Vital Hardware

For nearly 2,500 years sailors have relied upon the mechanical advantage provided by pulley blocks to overcome the strains of wind, weight, and water. These simple machines have played a tremendous role in shaping the history of seafaring. Since the rise of the Ancient Greek city-states, blocks have been essential to the operation of any sailing ship of more than a few tons. They have come to constitute one of the fundamental elements of ships' rigging, almost as basic and universal as masts, rope, or sails. By the 16th and 17th centuries, European navies and East India trading companies were regularly launching ships of more than 1,000 tons displacement carrying over 1,500 square meters of sail (Kirsch 1990:39). Controlling such an expansive rig required the mechanical advantage of several hundred rigging blocks of numerous sizes and specialized types. This thesis examines and analyzes the block collection recovered from one of the ships of this era, the Swedish royal warship *Vasa.* The purpose of this research is to determine patterns of block design, manufacturing methods, and placement within the rig. Ultimately, this will make it possible to deduce the social organization behind the production of this vital hardware in the Stockholm navy yard's blockmaking shop and assess the functional capacity of *Vasa*'s blocks and their impact on ship handling.

Vasa, lost just minutes into its maiden voyage in 1628, was raised from the bottom of Stockholm Harbor in 1961 after 333 years in its murky depths. Since its recovery, the ship has provided an extraordinarily informative glimpse into 17th century Swedish shipbuilding, rigging, and outfitting practices. The virtually intact hull and the concentrated debris field contain provisions, tools, and equipment from almost every part of the ship. Studies are planned or underway on every artifact group recovered from the *Vasa* wreck site in addition to numerous other research efforts investigating site-formation processes and conservation treatments. In 2006, a detailed study of the of rigging and gun tackle blocks was started. The collection recovered with *Vasa* is unmatched in scope or size by any other extant source of 17th century rigging hardware. A total of 412 intact blocks and 143 fragments were found in association with the ship—far more than were recovered from *La Belle* or *Santo Antonio de Tanna* or even the 16th century wrecks, *Mary Rose,* and 24M at Red Bay, Labrador. Many of *Vasa*'s blocks are extraordinarily well preserved, retaining tool marks and even lengths of cordage. The quantity and condition of these blocks provides an excellent opportunity to study this frequently overlooked, but critical type of hardware from a period of major social and technological change.

The research presented in this thesis was designed to use an examination of simple patterns of design, production, and usage evident in the material remains of *Vasa*'s rigging and gun tackle blocks to explore broader questions pertaining to the men who actually built and sailed *Vasa*. The blocks recovered from the wreck site provide a record of what types were fitted on the ship, in what sizes, what materials were used, and even how they were manufactured. The distribution of these blocks indicates their probable usage, permitting the creation of a partial rigging reconstruction to estimate what percentage of the rigging blocks survived, whether the current reconstruction of *Vasa*'s rig is correct, and the degree to which *Vasa*'s crew could depend on blocks for assistance in operating the ship. Gathering answers to these tangible questions forms a foundation for exploring more abstract questions about Swedish and broader Northern

European culture in the early 17th century. Combined with historical sources, this physical evidence makes it possible to compare *Vasa*'s blocks and rigging configuration to practices elsewhere in Europe, to ascertain the degree of foreign influence upon Swedish rigging design, and perhaps even to offer further clarity in the debate over whether patterns of ship design and outfitting can even be classified along national boundaries. Ultimately, the careful examination of the design, craftsmanship, and distribution of *Vasa*'s blocks, set against the background of 17th century Swedish history, reveals and reflects key aspects of contemporary naval technology, life on board, the rise of the modern nation-state, shipyard organization, equipment production, outfitting, and even the working environment of the naval blockmaker.

During the course of this research, it was found that, despite a reasonable volume of archaeological evidence, very little has been published on blocks. Although blocks are mentioned in numerous archaeological reports, meaningful analysis is rare (e.g. Rule 1982; Thompson 1988; Cederlund 1983; Green 1989; Marsden 2009). Historical sources offer little more substance on the topic. Few technical works on ship-fitting or seamanship, such as Darcy Lever's *Young Sea Officers' Sheet Anchor* (Lever 1808), George Biddlecombe's *The Art of Rigging* (Biddlecombe 1848), John Murphy and William Jeffers' *Nautical Routine and Stowage* (Murphy and Jeffers 1849), R. C. Anderson's *The Rigging of Ships in the Days of the Spritsail Topmast* (Anderson 1927), or even John Harland's *Seamanship in the Age of Sail* (Harland 1984), examine blocks in detail either. These works describe where certain types are to be placed in the rig, but do not discuss the structural composition of blocks, their production, their physical properties, or their importance to ship handling. The Englishman David Steel is the only author who has given thorough attention to blockmaking, describing typical designs, physical components, production processes, and the tools involved in his 1794 publication, *The Elements of Rigging and Seamanship* (Steel 1794b). In 1797, he published an improved version of that work offering more detailed explanations and more illustrations titled *The Art of Making Masts, Yards, Gaffs, Booms, Blocks, and Oars, as Practised in the Royal Navy and According to the Most Approved Methods in the Merchant-Service* (Steel 1797). Although Steel is thorough in his treatment of blockmaking, even he glosses over the importance of the block, dismissing a discussion of their significance to shipboard operations with the opening statement that “Blocks are well known mechanical instruments, possessing the powers and properties of pullies [sic]” (Steel 1794b:149). Indeed, to the weathered sailor the mechanical properties and supreme importance of rigging blocks to the operation of a large sailing vessel requires no explanation. For those less familiar with the role of rigging blocks, however, a brief discussion of their critical contribution to ship handling is worthwhile.

Blocks appear in many forms and can be rigged alone or in tackles to serve a wide variety of specialized shipboard functions, but the basic principal is the same; a block is a piece of independent hardware that allows a rope or line to pass freely around a sharp bend with minimal resistance. This simple function is essential to the operation of a complex sailing rig, for it provides the remarkable capacity to redirect the physical forces exerted through cordage without any appreciable loss of force. It is this basic mechanism that makes it possible to hoist a sail *up* a mast by pulling *down* on a line (Figure 1.1). A block at the masthead redirects the line and its pulling force 180° back down to the sail, the block’s free-spinning sheave ensuring that the energy is not lost to friction.

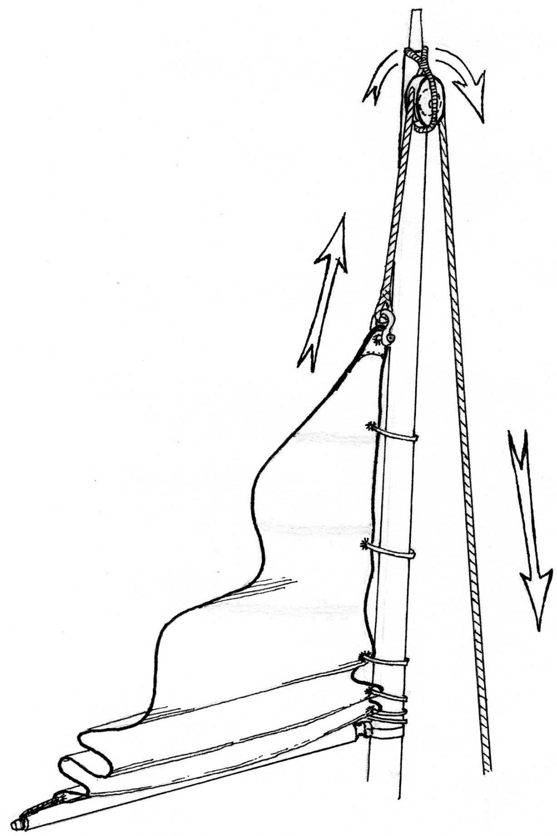


FIGURE 1.1. A block alters the direction of a pulling force and minimizes resistance at the turn (Drawing by Nathaniel Howe, 2011).

This ability to redirect pulling forces makes it possible to re-route lines around obstacles and fouling hazards and to position a line for an optimal angle of purchase on a sail or spar (Figure 1.2). Such arrangements often require the use of several blocks, guiding the line up from the deck, through the shrouds, and weaving up into the rigging to manipulate a sail or spar high above the deck. Each bend in the course of the line requires a smooth-running block to keep the line clear of obstructions and to pass the pulling force upward to the appropriate part of the rig.

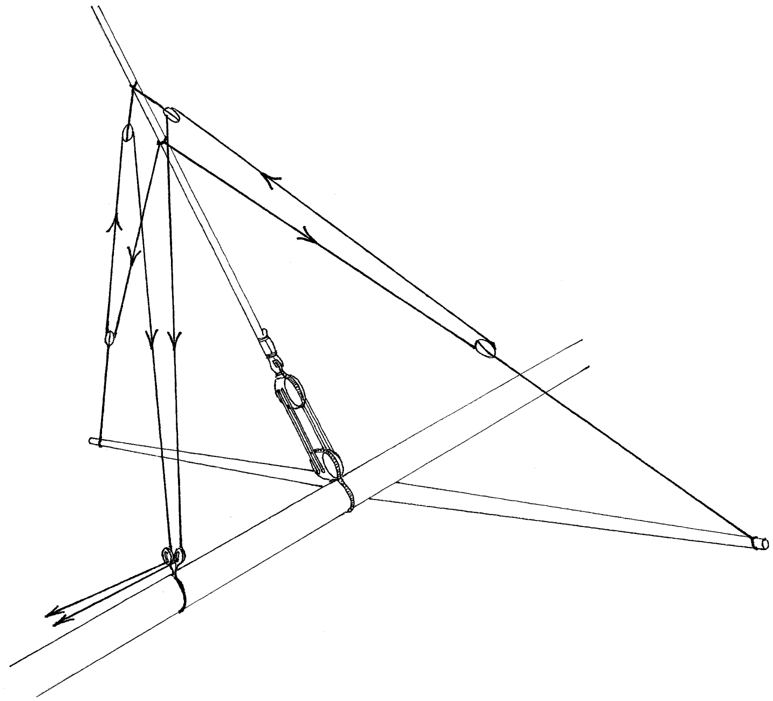


FIGURE 1.2. Multiple blocks can be arranged in a series, as shown in this diagram of the spritsail yard lifts, to redirect a line several times in order to avoid obstacles and fouling hazards and to obtain an optimal angle of purchase (Drawing by Nathaniel Howe, 2011).

Blocks are also often rigged to one another with a single fall passing between them several times to form a tackle (Figure 1.3). These simple machines multiply pulling forces by converting the length of pull into power, offering crews a mechanical advantage in hauling against heavy loads. Tackles are employed all over the ship for everything from hoisting the yards to tensioning the shrouds and hauling the guns into firing position. For all but the smallest sailing rigs, tackles are necessary to obtain the power needed to overcome the strains of wind, weight, and water.

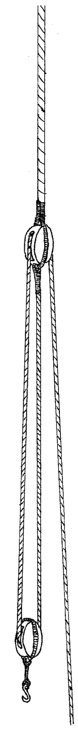


FIGURE 1.3. A pair of blocks can be rove together with a single fall passing between them several times to form a tackle, a simple machine that multiplies pulling forces (Drawing by Nathaniel Howe, 2011).

These two basic functions—redirecting and multiplying pulling forces—make the block an essential piece of hardware in the operation of sailing ships like *Vasa*. Applied in numerous configurations on deck and throughout the rig, the block and the physical advantages it provides can achieve virtually every action desired from hauling cannon and cargo to setting and striking the sails. No other article of shipboard hardware is so universally applicable to the operations of the vessel.

The rigging collection recovered with *Vasa* provides an extraordinarily informative look at the use of this vital hardware in the 17th century. No other collection of that age is so complete. At most shipwreck sites, blocks do not last long on the seafloor. Exposed above the hull, they are lost to attrition as salvagers cut them loose, the lashings rot out, marine organisms devour the wood, or particulates in the current simply erode them down into unidentifiable nuggets. Yet in the case of *Vasa*, 412 of the ship's estimated 600 blocks were recovered essentially intact. The survival of 68% of the rigging hardware provides an unparalleled look at rigging practices of the era—a key element in revealing how large warships like *Vasa* were actually rigged, manned, and operated.

Scope and Organization

This thesis examines and analyzes the rigging and gun tackle blocks found in association with *Vasa.* It begins with an exploration of block technology, typology, nomenclature, historical development, and typical configurations for placement in a 17th-century squaresail rig. Then the thesis shifts to focus on the blocks actually found with *Vasa,* looking first at form, then distribution at the wreck site, and finally interpretation of certain identifiable groups of blocks and a suggested reconstruction of the use and placement of these blocks in the rig. The final section delves into what *Vasa*'s blocks reveal about 17th century manufacturing processes in the Stockholm navy yard and generalizations extrapolated from *Vasa* regarding the employment of blocks aboard Swedish naval vessels of the period.

In the interests of maintaining an intelligible semblance of organization, this thesis arbitrarily separates fixed blocks mounted to the hull, deck, or spars from all flexibly mounted blocks. Although cheek blocks, D-blocks, sheaved fairleads, knightheads, as well as mast and spar sheaves are certainly blocks according to the functional definition presented here, these items are excluded from this study and are currently being examined by other researchers focusing on the hull, bitts, and spars. Interestingly, a similar division existed in British naval yards of the 18th century where, according to David Steel, producing some of these block types was the responsibility of the mastmaker, not the blockmaker (Steel 1794b:149). Consequently, for the purposes of this thesis the operative definition of a block might be better stated as "a *flexibly mounted* piece of independent hardware that allows a rope or line to pass freely around a sharp bend with minimal resistance." This practical division of fixed and flexibly mounted blocks establishes useful boundaries for the scope of this and other research, but it should be kept in mind that *Vasa*'s fixed blocks, although not discussed in this work, are indeed blocks as well.

Chapter 2. Background

Terminology and Definitions

The first blocks put to work on sailing vessels over 2,500 years ago were little more than their name suggests—a block of wood with a hole in it to guide a movable line as it passed around a bend. Centuries of development since that time, however, have introduced a few improvements, giving blocks more complex anatomy and specialized nomenclature. There is a margin of variability in this nomenclature. Most often it is simply the product of different cultural idioms; American sailors call the ends of a block the head and foot while British crews calls them the crown and tail, or arse. In other cases, variances in terminology are due to linguistic differences such as the Scandinavian use of *hus* (house) to describe what English speakers call the shell.

Perhaps the most unexpected discrepancy in the nomenclature of blocks is over the general definition. Many authoritative volumes on rigging or seamanship do not bother to define a block at all (e.g. Lever 1808; Murphy and Jeffers 1849; Anderson 1927; Harland 1984;). Those that do make an attempt invariably fall well short of formulating an accurate description (e.g. Lees 1979; Marquardt 1986). These typically offer only a vague description that either lumps blocks together with other items of rigging hardware such as fairleads, thimbles, and hearts that actually serve very different functions (e.g. Marquardt 1986:248; Hoving 2000:72) or restrict their definition to the most common form, “wooden casings with one or more sheaves” (Marquardt 1986:248; Kemp 1976:52), thereby excluding block types made with unusual forms or materials.

Even the esteemed rigging expert George Biddlecombe (Biddlecombe 1848) failed to fully capture a block’s essence in the written word. He defines blocks as

“Machines used in ships, and each block having one or more sheaves or wheels in it, through which a rope is put, to increase the purchase” (Biddlecombe 1848:3). While certainly true, his definition is incomplete. It only accounts for blocks rigged in tackles, neglecting all blocks rigged to guide or redirect lines without providing additional mechanical advantage. The omission amounts to well over half of the blocks in a typical squaresail rig. It also omits dead blocks that, although built without a sheave, do serve the same purpose and are usually interchangeable with small single blocks. Despite the wording of his definition, Biddlecombe certainly did not believe that blocks must be rigged in tackles in order to be considered blocks (later in his rigging treatise he discusses numerous “blocks,” such as quarter blocks, that are not rigged in tackles), but by defining a block as a machine for increasing purchase he inadvertently restricts the definition to just one function blocks serve. The inaccuracy of his definition is more the result of carelessness in defining a common item that, to him, must have seemed abundantly obvious. It is not a reflection of failing to understand the nature of a rigging block. Admittedly, a treatise on how to properly rig an entire man-of-war or trans-Atlantic merchantman can hardly be expected to include a detailed discussion on the theoretical definition of a block. Yet the lack of a carefully formulated definition from preeminent experts of his stature leaves persistent ambiguity on the matter.

Robert Kipping came closer to an accurate definition in his 1854 work, *Rudimentary Treatise on Masting, Mast-making, and Rigging of Ships* (Kipping 1854). Kipping defines a block as an item “used for various purposes in a ship, either to increase the mechanical power of the rope, or to arrange the ends of them in certain places on the deck; and they may be readily found when wanted” (Kipping 1854:84). This definition is much more inclusive, covering both tackle blocks and lead blocks used to reroute lines without providing mechanical advantage. Kipping's recognition that blocks serve in both of these capacities is a significant step toward an accurate definition. Yet, his version is also imperfect. He goes on to declare that all blocks have sheaves, thereby excluding the dead block, and while he includes lead blocks for guiding lines on deck, he overlooks those aloft. Most significantly, however, while Kipping does emphasize the two principal ways blocks are used, he does not actually define the fundamental function of a block.

The only prominent expert to really come close to properly defining a block is David Steel. He never provides a direct definition and, in fact, he actually dismisses the need to do so, stating that blocks are already "well known mechanical instruments" (Steel 1794). Yet in the blockmaking section of his 1794 treatise, *The Elements and Practice of Rigging and Seamanship* (Steel 1794b), Steel's wording and organization effectively convey a very accurate definition. In the opening passage, Steel focuses on the "properties and powers of pullies [sic]" as the defining element and acknowledges that "Blocks differing from the common shape" are still blocks (Steel 1794:150). He thus breaks from the common form-based definitions, placing greater emphasis upon function as the defining characteristic. This is reinforced later in the first paragraph by singling out items that lack the essential functions provided by pulleys, "To the blocks may be added the dead eyes, hearts, parrels, trucks, uphroes [sic], cleats, belaying-pins, toggles, thimbles, travelers, bull's eyes &c. these being all furnished by the block-makers" (Steel 1794b:150). Steel's introduction to blockmaking, although lacking a clear and direct definition, accurately alludes to the fact that it is the function of the pulley that is the defining characteristic of a block.

This thesis proposes a new and more accurate definition. Unlike traditional form-based definitions that define a block as a casing containing a pulley or context-based definitions citing blocks as components of a tackle, the one presented here is focused on the fundamental mechanics of a block. It is based on function rather than form or application. The functional definition of a block used in this thesis defines a block as *a piece of independent hardware that allows a line or rope to pass freely around a sharp bend with minimal resistance*. It is a somewhat longwinded definition, but it effectively resolves the ambiguities left by previous scholars. First, this definition excludes tackles. Despite the critical mechanical advantage they provide and the popular impression of the block and tackle as synonymous elements in one of mankind's most revolutionary simple machines, tackles are an application of block technology—not a defining functional characteristic of the block itself. A block, by itself, provides no mechanical advantage for hauling against a load. Its only mechanical advantage is over friction at the point where the line changes direction. Thus, although the tackle may be the block's most important contribution to the history of seafaring and the development of large sailing ships, it is the block's ability to pass a line around a sharp bend with minimal resistance that defines it. In fact, it is this ability that makes it possible to create tackles. This definition also brings dead blocks back into the fold while casting deadeyes, hearts, and fairleads outside the block family due to the very different functions they serve. Deadeyes and hearts are not intended to facilitate free passage of a line rove through them while fairleads usually do not significantly change the direction of a line.

Interestingly, the functional definition presented here matches the classification system for distinguishing blocks from other rigging hardware that was devised by sailors themselves. The form-based names sailors gave to various bits of rigging hardware like fiddle block or ram's head block seem arbitrary and simplistic. Yet, they actually reflect a solid understanding of fundamental functional differences. The system is remarkably simple. Hardware that actually functions as a block and allows a line to pass freely around a bend has the term 'block' as part of its English common name. Even those with highly unusual forms such as D-blocks, snatch blocks, and rack blocks are included. Items that serve a different function like deadeyes, hearts, or fairleads, however, do not have the term 'block' attached. The fact that this naming system—developed and maintained for centuries by the sailors who worked with the rigging and knew it intimately—should distinguish rigging hardware along the same lines as the theoretically derived definition presented here, serves to underscore the importance of function over form in defining a block.

According to the function-based definition introduced here, there are 412 blocks and 143 block fragments in the *Vasa* rigging hardware collection. The terms and definitions that will be used to describe those blocks and their component anatomy in this text are derived from a variety of historical sources, including Kipping and Steel, as well as more recent texts from modern maritime industries (e.g. Brady 1967). The terms include the following (Figure 2.1):

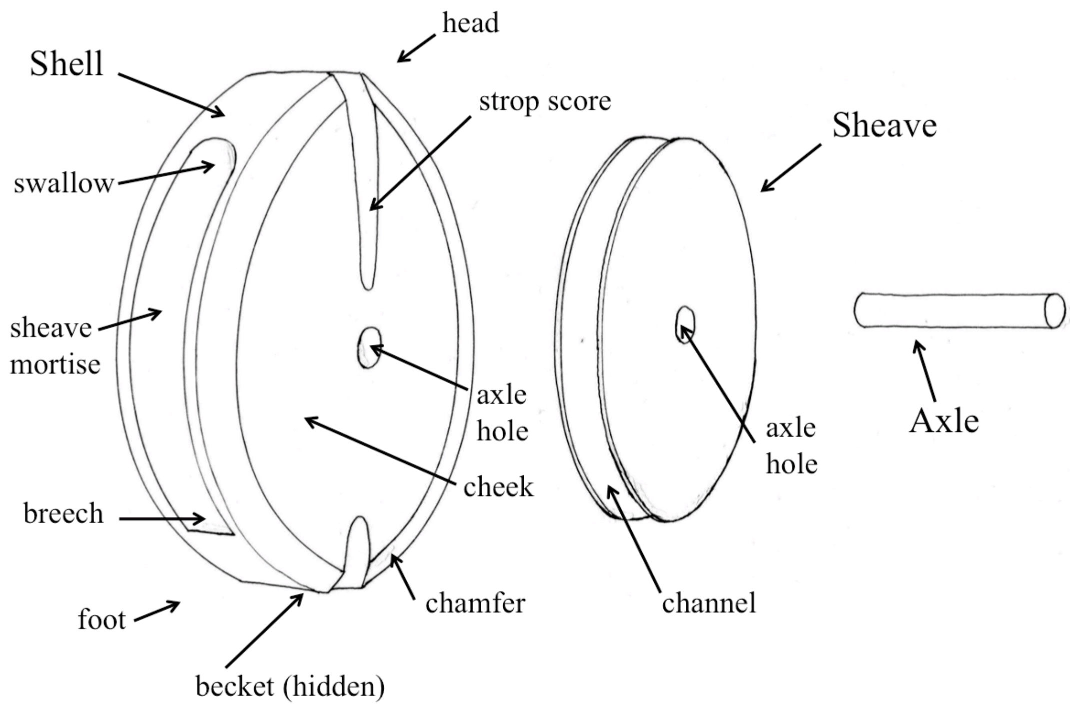


FIGURE 2.1. Anatomy of a common single block. Blocks with multiple sheaves have the same anatomical nomenclature plus a 'web' that divides the sheave mortises and offers extra support to the axle (Drawing by Nathaniel Howe, 2011).

<u>Block:</u> A piece of independent hardware that allows a line or rope to pass freely around a sharp bend with minimal resistance.

<u>Fall:</u> The moveable line passing through a block. Biddlecombe notes that some consider only the portion of the line that is hauled upon to be the fall (Biddlecombe 1969:12). This text recognizes the entire movable line as the fall, including the legs of a tackle.

<u>Shell:</u> The main body of a block. In some historical texts, the shell is occasionally called the body or the house. Shell is the term used in this thesis. The shell functions as a casing around the sheave (pulley), as a mounting for the axle, and as a guide for the fall running through the block. The form of the shell varies depending on the role and function of a

particular block. Most are elliptical, oval, or just simple cubes with rounded edges, but more complicated geometry is also common, producing shells that are diamond-, pear-, ‘G’-, or fiddle-shaped. Several other types are cut with specialized protrusions resulting in block shells resembling an acorn or a three-dimensional comma. Until the middle of the 19th century, these block shells were always carved from a single piece of wood and are consequently referred to as cut-blocks or mortised blocks. Later, wooden block shells were assembled from several pieces laminated together and known as made-blocks (Ashley 1944:521). Today, block shells are frequently made of laminated wood, steel, wood-sheathed steel, or synthetic materials such as plastic and carbon-fiber.

Sheave: The pulley inside the shell is called a sheave. In form, it is a simple wheel cut with a groove in its outer edge and a hole through its middle. The groove is designed to carry the fall around the sheave as it rotates on the axle. Sheaves may be made of wood or metal. Some are of composite construction consisting of a wooden disc fitted with metal bearings or bushings around the axle hole. The sheave was originally called a shiver and this term still appears in some British texts. Shiver was contracted to shiv after 1627 (Ashley 1944:521). Sheave is the spelling that will be used in this text.

Axle: The sheave rotates on an axle passed through a hole in the centre of the sheave and seated in the shell walls. The axle is also commonly referred to as a pin or spindle.

Sheave Mortise: The sheave mortise is a long, narrow passage cut through the shell into which the sheave is set. A block may have just one sheave mortise for a single sheave or it may have several sheave mortises. These can be arranged side-by-side to make use of a single axle, end-to-end with separate axles, or occasionally both configurations as seen in a ram's head block. All blocks have a sheave mortise except the dead block; it has only a swallow. In some texts, the sheave mortise is referred to as the channel or slot (e.g. Toss 1984:20).

Cheeks: The sheave mortise effectively divides the shell into two slabs called cheeks. These form the walls of the sheave mortise. In most blocks, the axle is fitted into holes bored through the middle of the cheeks. The strop is then fitted across the face of the cheeks, nesting in special grooves. The cheeks guard against impacts and tangling with other rigging. They also transfer the load from the sheave to the strop and guide the fall over the sheave. The cheeks can be shaped with rounded or chamfered edges (both seen on *Vasa*'s blocks) and can also be shaved thinner around the edges, giving the entire cheek a convex surface. This is called bearding the shell.

Web: The web is a thin portion of the shell between two sheave mortises. Webs are found on double, triple, and quadruple blocks with multiple sheaves set on the same axle.

Swallow: The swallow is the aperture where the fall enters or exits the block shell—or rather, where the fall is 'swallowed' by the block. The aperture is a gap between the edge of the sheave and the end of the sheave mortise. This gap is present at both ends of the sheave mortise, but typically formed with sufficient clearance to 'swallow' a line at only one end. In a dead block the swallow is the entire opening bored through the shell for the fall. In some texts, the swallow is called the feed (Bradley 1980: Figure 1).

<u>Breech:</u> The breech is the gap between the sheave and the end of the sheave mortise at the foot of the block (Brady 1967:93). Although it is the counterpart to the swallow, few blocks are built with sufficient clearance to admit the fall through the breech.

<u>Head:</u> The head of a block is the end that is secured to a fix point or a load. The swallow and the fall also pass through this end. In some cases, the head is referred to as the crown, top, or upper end regardless of the block's actual orientation. David Steel calls this end the arse (Steel 1794b:150), a term breaking from the pattern of perceiving of this as the anterior end of the block. He is the only one to do so.

<u>Foot:</u> The foot of a block is the end opposite the fastening (hook, pendant, or strop collar) and does not carry the fall around the sheave. This end is also often referred to as the tail, base, heel, bottom, lower end, or frequently as the arse (Thompson 1988:102). Again, David Steel departs from convention and calls this end the breast—a term breaking from the notion of this being the posterior end of the block (Steel 1794b:150).

<u>Strop:</u> The strop, or strap, is a length of cordage or iron passing around the block shell that is used to fasten the block to a fix point or to a movable load. The strop also covers the ends of the axle, holding it in place.

Strop Score: The strop score is a shallow depression carved in the face of the shell. It forms a channel to seat the strop and prevents it from slipping off of the block. The carving of strop scores differs significantly between regions and time periods. *Vasa*'s blocks feature a fairly common method with the scores running lengthwise down the face of the cheeks, gaining depth toward the ends of the block. At the head, the scores are typically cut on both sides while at the foot the score wraps around the end of the block and extends part way up each cheek face. Some strop scores, such as those carved into some of the blocks rigged on *Mary Rose* (1545) and the Serçe Limanı vessel (11^{th} century A.D.) actually tunnel through the head of the block shell (Marsden 2009 and Bass 2004).

Standing End and Working End: Any line employed aboard a ship has two ends. The standing end is affixed to a block, sail, hook, timber, or spar while the working end is only temporarily made fast and may be cast off and hauled upon by the crew. The working end is the end to which force is applied to accomplish a desired action. A line rigged through a block as a fall also has a standing end and a working end defined in the same manner.

Becket: An attachment point for fastening the standing end of a fall to the foot of a block. A becket involves passing a line under the strop at the foot. Often this requires that a small depression be carved out of the block shell to allow the end of the fall to pass under the strop without popping it off. The fall is then eye-spliced or simply doubled back on itself and secured with seizings. Both the shallow depression carved in the block and the attachment of the standing end of the fall to the foot of the block are referred to as a becket.

Tackle: A tackle is a simple machine for obtaining a mechanical advantage to increase pulling power that consists of two blocks rove together with a single fall. Tackles come in a range of configurations (See Chapter 4, Figure 4.4), but in order to constitute a tackle the fall must pass between the two blocks at least twice. The mechanical advantage and the name of the tackle (e.g. two-part, three-part, four-part tackle etc.) are determined by the number of times the fall passes between the two blocks. Dividing the load by the number of cords directly supporting it will yield the amount of force needed to hold the working end.

Block Types

During the Age of Sail, riggers and sailors developed a remarkable variety of block types. Over time, a nomenclature system was developed to sort and identify them. The system for naming blocks is slightly irregular, but it generally holds to a simple multi-tier pattern. Each tier classifies blocks into progressively smaller sub-types with more specific titles (Figure 2.2).

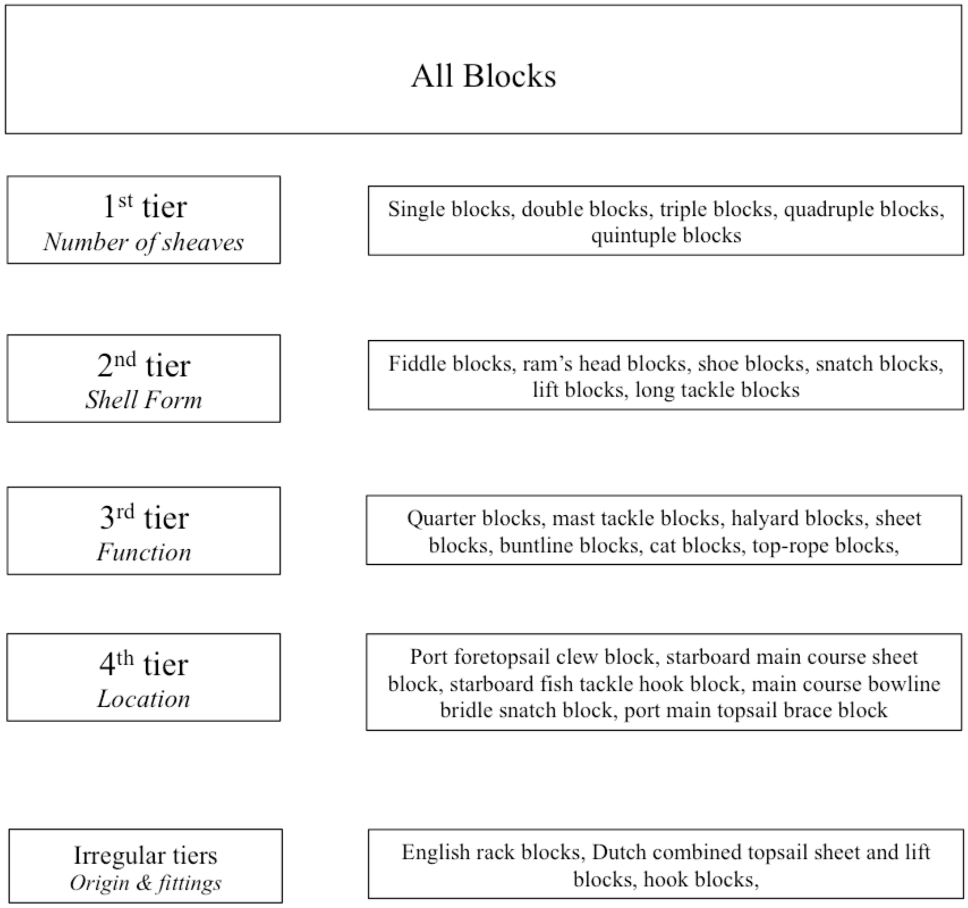


FIGURE 2.2. The block nomenclature hierarchy. Each tier assigns a different name to a block based on the number of sheave, the shell form, function, and location of the block in the rig. Note that all the examples are plural except those in the 4th tier. In the 4th tier, each and every block on a ship has its own title differentiating it from all other blocks onboard. The irregular tiers label blocks based on their national origin or special fittings (Diagram by Nathaniel Howe, 2011).

The first two tiers in the nomenclature system define blocks entirely by form, rather than function or context. These primary tiers therefore apply to all blocks whether they are rigged aboard ship for a specific purpose or loosely stacked in a chandlery warehouse—or even if they are scattered across an archaeological site. The higher tiers in the typology, however, are generally determined by the block's placement and function in the rig. Accordingly, the names for a general block type will tend to reflect the form while more specific titles will reflect function. Together, the four tiers of the nomenclature hierarchy classify blocks by the number of sheaves they carry, the form of the shell, their general function in the rig, and finally the block's specific location in the rig.

First Tier: The first tier classifies blocks into basic types based on the number of sheaves they carry. A block with one sheave is referred to as a single block, two sheaves make a double block, and three sheaves make a triple block (Figure 2.3). Anything higher is dismissively labeled as a multiple block while a block with no rotating sheaves at all is somewhat understandably known as a dead block (the lack of moving parts making it seem 'dead').

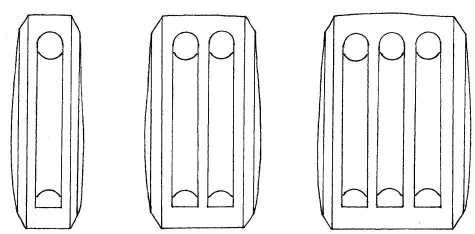


FIGURE 2.3. In the first tier of the nomenclature, blocks are named by the number of sheaves they carry (Drawing by Nathaniel Howe, 2011).

Second Tier: Next, the second tier assigns a sub-type to the block. The sub-type is more descriptive, being based on the shape of the shell. Most often, the sub-type name relates the block shell to other familiar shapes producing names such as shoe block, fiddle block, and ram's head block. In most cases, these shapes are created by the arrangement and relative sizes of the sheaves. For instance, a double block with sheaves arranged end-to-end rather than side-by-side is a sub-type known as a sister block. But if those sheaves differ in size, the block shell acquires a figure-of-eight form known as a fiddle block. Twist those sheaves 90° along the longitudinal axis of the block and the shell assumes another form known as a shoe block, the silhouette resembling a footprint.

Yet all of these—the sister block, the fiddle block, and the shoe block—are sub-types of the basic double block. Among these blocks are several types easily classified by their distinctive shapes, but actually given function-based names. Lift blocks, for example, have a unique form that sets them apart from other blocks, yet they are named for their function in the yard lifts. The same is true for snatch blocks. Their 'G'-shaped shells make them very distinctive, but they win their catchy name because of their specialized function as a block that allows the fall to be 'snatched' out. Although their names are function-based, these names can be applied to these blocks regardless of context and actually refer to specific and readily identifiable forms.

Third Tier: The third tier is much more specific and is based on context, focusing on a block's general function in the rig. Here you find brace blocks, halyard blocks, quarter blocks, sheet blocks and a dozen other sub-types. These are titles reflecting specific functions. Yet, for each title, there may be numerous blocks that can be classified under a single name such as brace block or quarter block. Therefore the nomenclature system must get more refined still.

Fourth Tier: The fourth and final tier in the block nomenclature system is extremely specific and is strictly based on context. The titles assigned at this level identify and distinguish each and every individual block by its placement in the rig. No block has the same title as another. In the fourth tier, blocks get long-winded titles such as *starboard fore-topsail sheet block* or *port sprit-topsail brace block, port mizzen-topsail leech line block* or *lower garnet tackle block*. Each name reflects an individual block with a specific purpose and placement in the ship's rig.

Intermediate & Irregular Tiers: There are a few intermediate and irregular sub-typologies in the nomenclature system. Some blocks are given a special title because of certain fittings. For example, a single or double block with an iron strop forged into a large hook at the head is termed a hook block. In other cases, a block may be named for how it is rigged. Pendant blocks, for instance, are rigged from pendants while leg and fall blocks are rigged between lines forming a leg and a fall, and halyard blocks are rigged as part of a halyard. Other blocks are sorted into further sub-types based upon the origin of its form. The French rack block, for instance, is distinguishable from other rack blocks because of a special form indicative of its origin. The same is true of the Dutch combined-topsail-sheet-and-lift-block, a type that is strikingly different than those produced by the English, French, or Spanish.

Refining the name: Neither sailors nor maritime historians have ever described a block by all four names bestowed upon it by this nomenclature system. Typically only one or two of the titles are retained to identify it and the rest are discarded as redundant or uninformative. Some blocks are referred to by a fourth tier title while others may end up with a second tier title. Exactly which titles are used depends on several factors—and just to keep things interesting, a block's name may change from one situation to the next.

The basic rule of thumb is that the name used is the title that best distinguishes a block from other blocks. This of course, depends upon the context and why it is being differentiated in the first place. If a spare is being brought on deck to be rigged, an order may be given to bring up a *large single block* to be rigged as a new *starboard fore-course sheet block*. It is the same block, but goes by different names in each context. This is because in the rigging locker the only way to differentiate the desired block from the assortment of other types is by size and form. But once brought on deck, it is assigned a specific function and location within the rig and acquires a specific title. In each setting, the block is best identified by contrasting it with other blocks in that context. This means that selecting a concise name for any particular block is a shifting target. Modifying that basic rule of thumb to account for context produces a very consistent system for whittling the titles down to something manageable and effective. Ultimately, *the name used to identify a block in any particular context is the term that best distinguishes it from other blocks in that context*. It may sound like double-talk, but it works to effectively refine the name down to a term for practical use, either at sea or in academic discussion.

The context of a particular block is not limited to whether it is rigged aboard ship or not. Context can also refer to who is using the terminology. Many of the names appearing in rigging literature are academic titles. Scholars often compare different ships and rigging methods and therefore have reason to differentiate between a French rack block from an English one. The sailor, however, has just one ship in front of him with one type of rack block. Even if that ship *were* rigged with two different types for some inexplicable reason, the sailor would still refer to them by their placement and function in the rig rather than by their national style. In daily operations at sea, it does not help much to recite the origin of a rack block.

This text discusses *Vasa*'s rigging and gun tackle blocks in several different contexts. As a scholarly work, the scholar's comparative terminology will be present; however this thesis also views the rig from the perspective of the chandler, rigger, and sailor. This opens the door to include almost every term in the block nomenclature system. For example, the chapter discussing the various block types found in association with *Vasa* focuses on the number of sheaves and the form of the shell (1st and 2nd tiers). The chapter covering the probable placement of the blocks in the rig is much more centered on the general function and specific placement of individual blocks in the rig (3rd and 4th tier titles). The chapter comparing *Vasa*'s rigging hardware to other archaeological collections looks at form (1st and 2nd tiers), placement in the rig (3rd and 4th tiers), and regional rigging practices (intermediate tier). The use of multiple titles to describe individual blocks in these chapters can be confusing, but by sticking to that helpful rule of thumb that *the name used to identify a block in any particular context is the term that best distinguishes it from other blocks in that context*, it is possible to keep the discussion comprehensible.

Chapter 3. Blocks from Antiquity to the 17th Century

Prelude to Blocks

The blocks recovered with *Vasa* are part of a complex rig, but certainly not as novel or innovative as the ship's double gun decks or its uniform armament. They are the continuation of an ancient technology that has been in use for at least 2,500 years. The earliest blocks are believed to have been simple pulleys mounted on posts or A-frames and used to reduce chafing in well bucket hoists (Albenda 1972:42-43). Exactly when blocks were first introduced aboard ships is difficult to deduce. Early advances in boatbuilding are typically accredited to the Egyptians who began developing practical watercraft over 7,000 years ago (Vinson 1994:11). For two millennia these were no more than pole or paddle driven rafts of bundled papyrus reeds, but by 3,500 B.C. the Egyptians were starting to rig small squaresails on these craft (Casson 1994:14; McGrail 2001:19-22, 33; Vinson 1994:11). The sailing rigs were simplistic, but effective in allowing these vessels to ride the wind up the Nile. The rig was small and could easily be raised and controlled by hand using light cordage run directly from the spars (Casson 1994:14). Later in the third millennium, the development of stronger, wooden hulls permitted the construction of more substantial vessels capable of venturing beyond the Nile and out onto the Mediterranean (Casson 1994:15). Larger, broader sails rigged on bipod masts were made to propel these ships (Figure 3.1). Simple halyards thrown over a cross timber at the masthead had been in use almost from the dawn of sail (Casson 1971:382), but these larger sailing vessels with heavier sails created the first genuine need for blocks onboard ancient watercraft. At this juncture, 5,000 years ago, sails had become large enough to overwhelm the muscle of a ship's crew and the sharp 180° turn of the halyard at the masthead created a point of friction capable of posing a serious limitation to the safe operation of the vessel.

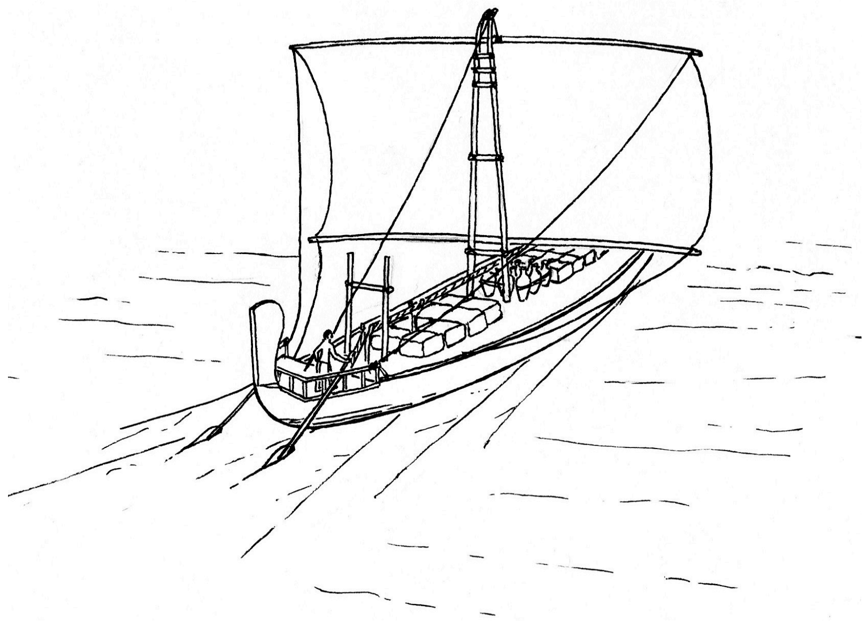
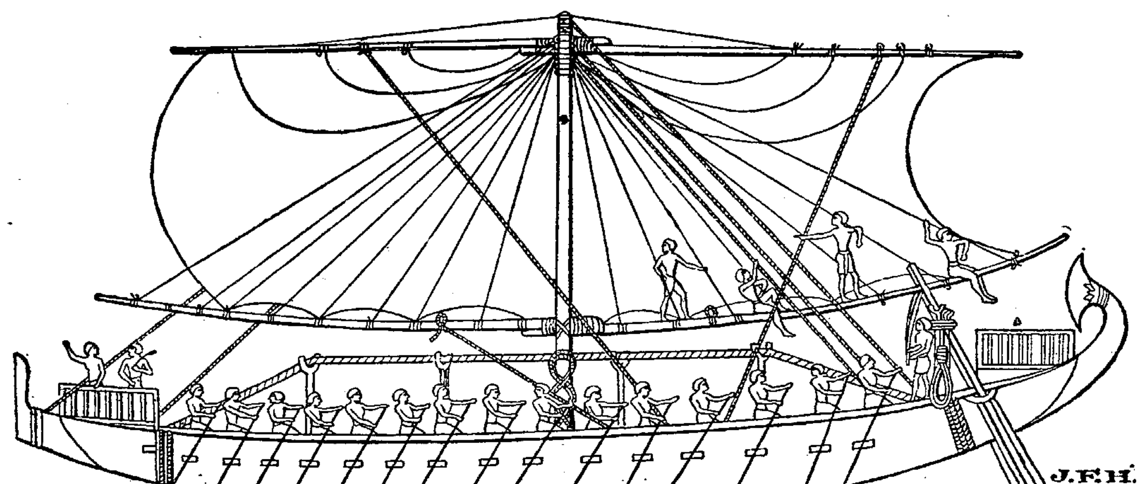


FIGURE 3.1. An Egyptian vessel with a bipod mast and no blocks used anywhere in the rig. Even the halyard has no block, instead simply being passed over a cross timber at the masthead (Drawing by Nathaniel Howe, 2011).

Despite Ancient Egypt's many monumental achievements and its prowess in shipbuilding, there is no evidence in written accounts or in the archaeological record indicating that the Egyptians ever adopted the pulley for applications at sea or even on shore (Casson 1971:20; Block 2003:3). Even after the pulley block came into use elsewhere in the ancient world, Egyptian vessels continued to rely upon the combined strength of large crews and cautious handling in windy conditions to keep their larger vessels under control. Tomb paintings and detailed funerary boat models—particularly those depicting Queen Hatshepsut's naval and merchant fleets of ca.1450 B.C.—offer detailed representations of the rigging (Figure 3.2). Yet, none show any indication of blocks on an Egyptian vessel (McGrail 2001:41-43; Casson 1994:21; Vinson 1994:23, 32, 39-40). By the early years of the New Kingdom the Egyptians had developed special fittings mounted at the masthead that could be considered to be the precursor to the block. These fittings were simple wooden or metal rings fixed to the masthead of pole masts for the purpose of allowing the halyards to make the 180° bend over the masthead with minimal resistance (Figure 3.3). Functionally, these rings served the same purpose as blocks. Yet, these rings were not independent pieces of hardware and never included free-spinning sheaves to reduce resistance (McGrail 2001:41). At best, these masthead rings could be considered a sort of proto-block. Blocks as defined in this chapter, however, were not in use and were not known in Ancient Egyptian civilization (Casson 1994:21; Cotterell and Kamminga 1990:89).



Egyptian ship on the Red Sea, about 1250 B.C. [From Torr's "Ancient Ships."]
Mr. Langton Cole calls attention to the rope *truss* in this illustration, stiffening the beam of the ship. No other such use of the truss is known until the days of Modern engineering.

FIGURE 3.2. Later Egyptian vessels with much larger and more complex rigs were fitted with masthead halyard rings (Wells 1920).

FIGURE 3.3. This photo and inset show the masthead rings used for redirecting the halyard back down to the deck prior to the introduction of blocks. This painting is on an Athenian vase from the 5th or 6th century B.C. and depicts Odysseus lashed to the mast to prevent himself from falling to the temptations of the Sirens (Photo courtesy of the Trustees of the British Museum).

Other early civilizations in the Mediterranean also appear to have lacked block technology. The ships depicted in the Thera Frescoes (ca. 1650 B.C.) found in the ruined Aegean city of Akrotiri show sizable ocean-going sailing vessels, but no sign of blocks or a rigging configuration that would really require them. These ships are, however, fitted with the same masthead halyard rings seen in Egyptian vessels (McGrail 2001:112-116, 119). The ships built and sailed by the Phoenicians, the reputed ancient masters of seafaring, frequently appear in Egyptian tomb paintings, Greek art, and Assyrian iconography. Yet, none of these depictions exhibit any indication of blocks being used in their rigs either (McGrail 2001:128-132). Even though large sailing vessels were not uncommon in the Middle and Late Bronze Age, the historical and archaeological record suggest that block technology did not play a role in establishing dominance over maritime trade routes in the ancient world. Until the 6th century B.C., it appears that ships were kept under control by virtue of their relatively small size, the simplicity of their rigs, and the brute strength of their crews.

Early Appearances of the Block

The scant archaeological and iconographic evidence available suggests that the pulley was invented in the Levant sometime around the 9th century B.C. and was most likely developed for raising and lowering well buckets. In a Syro-Palastinian bas-relief recounting the struggles of a walled city under siege during 9th century B.C., a pulley is shown being used to lift water from a deep well (Figure 3.4). At present, that is the oldest known reference to a pulley (Albenda 1972:42-43).

FIGURE 3.4. A Syro-Palastinian bas-relief from the 9th century B.C. depicting the struggles of a walled city under siege (Reg. No. 118906). In this scene a pulley is shown being used to lift water from a well. The attacking Assyrian army is cutting the well bucket from its fall (Courtesy of the Trustees of the British Museum).

It is not known exactly when pulleys were first fitted on ships. Given their potential for seafaring service, it might not have been long after their initial invention. The first indications of blocks employed in a maritime context are found in Greek iconography and folklore. An Ancient Greek black-figure ceramic cup from the 6th century B.C. shows what is thought to be a pirate galley overtaking a merchantman. Both are under sail and it appears that the galley has blocks rigged in the braces and halyards

(Casson 1994:45) (Figure 3.5). It is difficult to determine whether the decoration on the cup actually depicts blocks in the rig or if they are merely blotches left by the artist's brush, but the symmetry between port and starboard as well as the logical positioning of these blotches lends weight to the interpretation that they may indeed be rigging blocks. If so, this depiction shows blocks rigged to serve important functions aboard a ship approximately 300 years after the oldest known reference to a pulley being employed in any capacity.

FIGURE 3.5. An Ancient Greek black-figure ceramic *kylix*, or drinking cup, from the late 6th Century B.C. (reg. no. 1867,0508.963) shows a pirate galley under sail that seems to have blocks rigged in the braces and halyards (Courtesy of the Trustees of the British Museum).

The written record of block technology also dates to Ancient Greece. In Plutarch's biography of Archimedes, he describes Archimedes' demonstration of the power of blocks and tackles for King Hieron II of Sicily by single-handedly hauling a large warship off the beach and into the harbor around 250 B.C. Although this is the oldest written description of blocks being used in a maritime application, the story's focus on blocks being arranged in complex tackles for multiplying forces implies that, although tackles were a relatively new concept, blocks had served in their simpler capacity of redirecting pulling forces for some time.

Based upon the historical and iconographic sources, it appears that blocks went into use aboard ships within a century or two after 900 B.C. when the pulley seems to have been invented. During that period the Greeks and Phoenicians were beginning to ply the Mediterranean in progressively larger vessels and the need for low-friction rigging hardware and mechanical advantage to handle these ships required new rigging technologies (Casson 1971:170-172). Given the usefulness of pulleys in applications ashore, it likely did not take long for innovative seafarers to employ them on the water. The designs they developed served the intended purposes well and remained in use for at least another 300 years. Elsewhere in the world, similar developments were in motion. Chinese references to the use of blocks date back to the 2nd century A.D. (Needham 1965:95-96), although some scholars assert that the linguistic roots for the device appear to be much older, perhaps dating back as far as the 5th century B.C. (Cotterell and Kamminga 1990:90; McGrail 2001:357).

The Archaeological Evidence

Since blocks were first taken to sea over 2,500 years ago, they have been developed from simple chunks of wood with a hole bored through the center into a variety of highly specialized block types serving a wide range of shipboard functions. Fortunately, examples have survived in the archaeological record dating back almost to the beginning of their usage at sea. These examples provide an excellent look at the ways in which block design and construction changed over the millennia. This section examines blocks recovered from archaeological sites dating to different historical periods.

Blocks from Ancient Greece

The oldest rigging blocks ever found date to the Hellenistic Period, approximately 600 years after the invention of the pulley. These earliest surviving examples were recovered with the Kyrenia wreck, found off the north coast of Cyprus in 1965. The ship was a Greek merchant vessel, lost about 298 B.C. with a cargo of almonds, millstones, and 400 amphorae of wine and olive oil. The ship's heavy cargo drove it into the bottom, preserving the wooden hull and the ship's contents in the anoxic clay (Bass 2005:72, 76). Among the objects preserved were three wooden rigging blocks found in the stern among an assortment of other rigging gear (Figure 3.6). A full report on these blocks and the rest of the rigging remains is forthcoming (Laina Swiny 2011, pers. comm.), but a brief description of the blocks' form and condition can be given here.

FIGURE 3.6. The oldest blocks in the world, found on the Kyrenia wreck of 298 B.C. The two dead blocks are in the upper left and right corners. The object between them is a rigging toggle. The large single block in the center has a rotating sheave and was probably the main halyard block (Photo by Nathaniel Howe, 2011).

All three have piriform (pear-shaped) shells. The two smaller blocks are dead blocks, made without a rotating sheave. These are between 100mm and 120mm long and each is carved from a single piece of wood. The wear patterns at the breech show that these indeed functioned as blocks rather than as fairleads, deadeyes, or hearts. Although dead blocks are not often used on ships due to the greater resistance caused by not having a rotating sheave, such blocks would have been sufficient for the loads to be encountered on a small vessel such as the Kyrenia ship.

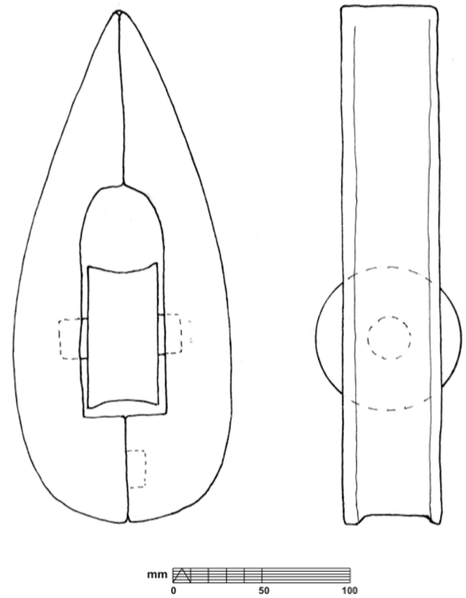


FIGURE 3.7. Front and side views of the Kyrenia block illustrating the two-piece shell, the axle pins, and the mortise and tenon joint between the shell halves (Drawing by Nathaniel Howe, 2011).

The larger single block is 265mm long and also has a flat, piriform shell (Figure 3.7). It is only 60mm thick, so the 75mm sheave projects beyond the cheeks on both sides. Unlike the one-piece dead blocks, the single block is carved from three pieces of wood. Two of these form the shell. The seam between the two halves runs down the center of the shell and the both pieces are carved with a mortise and tenon to lock them together at the foot. It is thought that the shell is probably mulberry, beech, or a species of *Pistacia* (Oleson 1983:161). The third piece of wood forming the block is carved to form a one-piece sheave and axle. To achieve a round sheave with minimum effort, it is made from a slice of a trunk or limb, the grain radiating out to the circumference. The block seems to have seen considerable use as the mortises in the shell made to receive the axle pins are heavily worn at the lower end (Oleson 1983:161).

The Kyrenia block's distinctive form with the two-piece piriform shell, the small one-piece sheave and axle, and the sheave projecting beyond the cheeks seems strange today, but appears to have been a common block design in the Greek and Roman worlds. Five other blocks of the same design and construction have been recovered from Roman seaport and wreck sites including Chrétienne C (2nd century B.C.), Agde D (1st century B.C.), Cap del Vol (late 1st century B.C.), Fos-sur-Mer (late 1st century B.C.-early 1st century A.D.), and Caesarea (1st century A.D.). All of these closely resemble the Kyrenia block, but are smaller (130mm-200mm) and somewhat stouter in form (Oleson 1983:160-161). An excellent survey of these ancient blocks was published in the *International Journal of Nautical Archaeology* by John Peter Oleson (Oleson 1983).

A peculiar detail seen in virtually all of these ancient blocks is that the strop score is cut as a flat recess around the circumference of the shell. For blocks stropped with cordage, a rounded recess is better for firmly seating the strop. It is possible that the Greeks and Romans were making strop pendants out of leather strapping or flat braided line, thus calling for a flat strop score. Yet the teardrop shape of the blocks suggests they were expected to seat in the spliced or seized eye of a cordage pendant.

Another oddity is that essentially all of them have small holes bored through the head. Caesarea, Agde D, and Cap del Vol all have a pair of these holes. The Kyrenia block may have had this feature too, but part of the head is missing. Oleson believes these holes were for lashing the two halves of the shell together, but notes that this should not have been necessary with a strop encompassing the block (Oleson 1983:166). Swiny, observing that Kyrenia's two dead blocks each have a single hole bored through the head of their one-piece shells, believes that a thin piece of twine was passed through these holes to lash the block to the strop, preventing it from shifting or rotating in the eye of the strop (Laina Swiny 2011, pers. comm.). If this conclusion is accurate, it supports the assumption that the flat strop score did not hold the strop as well as perhaps intended, suggesting that the strop may have been conventional cordage.

The sheaved Kyrenia block is thought to have been a halyard block (Oleson 1983:166). It is approximately the right size for the vessel. Yet, Oleson believes these blocks served another use. Most of the 'Caesarea type' are significantly smaller than Kyrenia's and date to a period when ships were growing larger. Moreover, the small diameter of the sheaves—perhaps better termed rollers—and the lack of large cheeks to provide a fair lead for the fall, would have made these blocks cumbersome and inefficient to operate. Oleson believes these piriform sheaved blocks were more likely part of ships' standing rigging than their running rigging. The notion that sheaved blocks predated deadeyes and hearts for tensioning the standing rig is counter-intuitive, simply because it uses a more complex hardware, but it is nonetheless a valid postulation. It is certainly plausible and elements of the standing rig typically last longer on wreck sites than the running rig, a fact perhaps reflected in these ancient finds.

Blocks from the Roman Era

Dozens of wrecks from the Roman Period have been excavated and at least a few of those were found to include rigging elements. In other cases, Roman rigging hardware has been found ashore in port cities. In addition to the Kyrenia type blocks that were also found at Roman sites, three other finds are worthy of examination; the Lake Nemi vessels, the County Hall wreck, and the block found in a temple at the Corinthian port of Kenchreai.

In 1929, two enormous Roman barges, each over 70m long, were partially excavated from the bottom of Lake Nemi, just north of Rome. These have been dated to the 1st century A.D. (Steffy 1994:71). Although these were not sailing craft, a large block was found in association with one of the barges (Figure 3.8). It is 1.08m long with a 0.50m-diameter sheave and has a unique design with an open breech (Ucelli 1950:182; Shaw 1967:392). This is not seen in any other block found in a maritime context until the 19th century because the open breech significantly weakens the block shell. To compensate for the open breech on the Lake Nemi block, the shell is bound in iron banding. It is believed that this block was used to handle the barge's heavy mooring hawsers (Shaw 1967:392). Unfortunately, this block was destroyed by German troops along with the Lake Nemi vessels in 1944 (Shaw 1967:392).

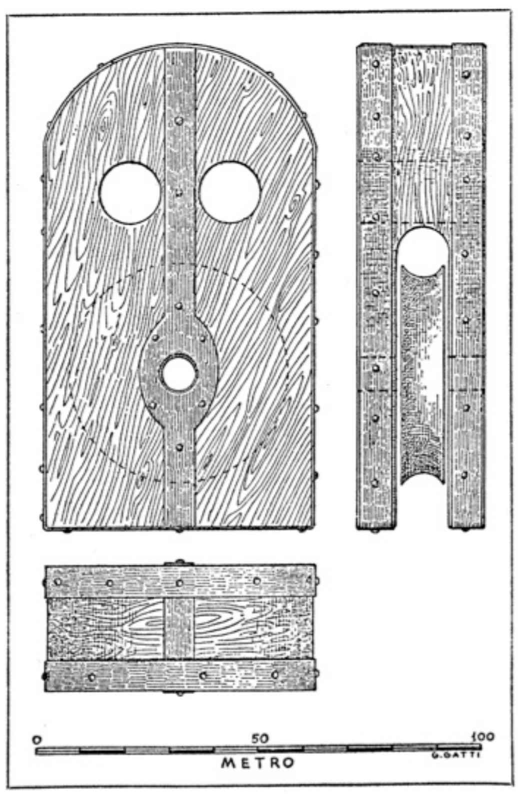


Figure 3.8. The large block found with the barges in Lake Nemi. The open breech is the most unusual feature of this iron bound block suspected of having been part of the mooring system for the barge (Drawing from Ucelli 1950:182).

In 1910, the remains of another Roman vessel were found at County Hall in London (Marsden 1974a:55). The ship was dated to the late 3rd century A.D. and among its contents lay a lone double block shown in Figure 3.9 (Shaw 1967:393). The oblong block shell is only 16cm long, making this an unusually small double block. Both sheaves are missing and the shell has suffered some shrinkage, but there is no staining, ghosting, or other indications of any metalwork being part of this block. Like most blocks in the era before the enormous ships-of-the-line, this one is a purely wooden device.

The most striking variance in the form of the County Hall ship's double block is the presence of a pair of pendant holes at both ends of the block. The holes at the foot of the shell probably served as a becket for securing the standing end of the fall. Those at the head of the block, however, are much more difficult to explain. In part, this is because the extreme head of the block is broken off. At first glance, these holes appear to be conventional pendant holes. Yet, the block also has a deep strop score around the shell, suggesting the block hung in the eye of a strop, not by a pendant secured to the head (Marsden 1974a:63). One possible interpretation is that both were true. The block may have hung from a pendant secured to the two holes at the head. A strop then wrapped around the block to prevent it from splitting, but did not serve any role in affixing the block to anything else. A second possible interpretation is that the strop tunneled in to the head of the block and emerged from the holes at the head. A third interpretation is that the holes in the head of the block were used to rig lashings securing the strop to the block as on the Kyrenia blocks. A fourth possibility might be that one set of apparent pendant holes was actually for inserting wooden pins that would serve as a belaying point. If so, it would be the earliest example of a block with a built-in belaying point by nearly 1,600 years (Witsen 1690:350). A fifth possibility is that the two tackles were rigged side-by-side through this block. Each was becketed to one of the lower holes, passed around sheaves in another block, then back to the sheaves in this block, one more pass around the other block, and finally passing through the holes at the head of the County Hall block to be brought back down and belayed (Fred Hocker 2011, pers. comm.).

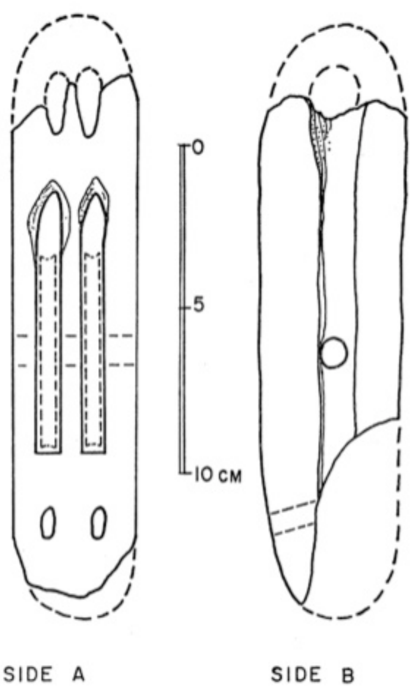


FIGURE 3.9. The County Hall double block is fairly small, but its actual length is unknown as both ends are broken off (Drawing from Marsden 1974a:55).

Later, in the mid-1960s, archaeologists recovered what appeared to be a large double block (Figure 3.10) from a partially submerged temple at Kenchreai, the eastern port of Corinth. The site has been dated to the 4th or 5th century A.D. The block was largely intact and still contained its two wooden sheaves. Measuring over 70cm in length, the entire block was made of wood without any indications of metal parts (Shaw 1967:389-391).

The most remarkable aspect of this block is the unusual shape of the shell. It is made with long, narrow projections off each end. At what appears to be the head of the block (based on the shape of the sheave mortises) is an 18cm-long wedge shaped projection. At the foot is a 13cm-long cylindrical projection (Shaw 1967:389). These are heavily eroded and difficult to identify. They may have been for securing the working end of the line or the alleged block may have actually been a bitt and these projections are fragments of the heavy timber housing the sheaves. Little else can be said about this block or even whether or not it was used aboard a ship. Although it was found in a port city, its find location in a temple suggests it could just as easily have been used in construction or commerce ashore.

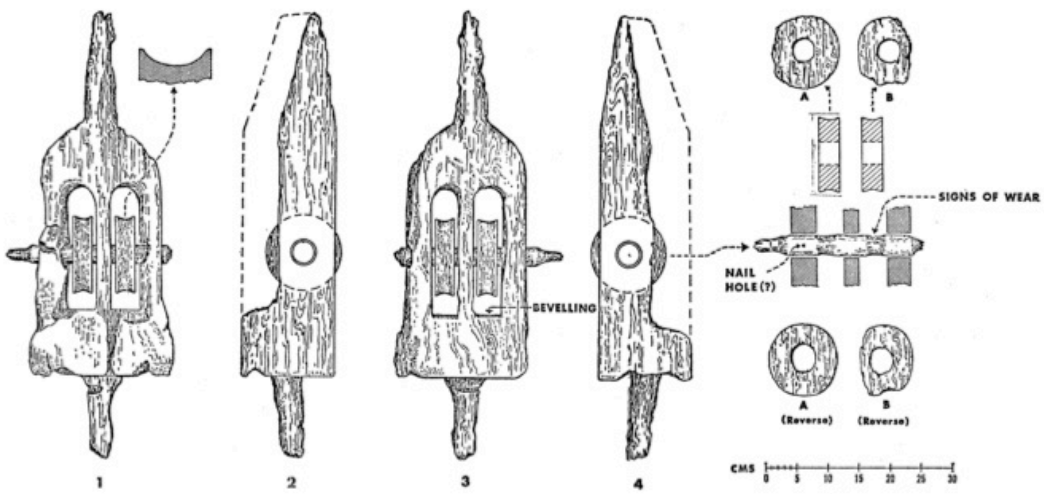


FIGURE 3.10. The double block from Kenchreai (Drawing by Susan Katsev, ca. 1966, published in Shaw 1967:390).

Based on these rare examples, it appears that the blocks of the Roman era were typically wooden, but sometimes had iron bands nailed to the shell for reinforcement. As ships and lifting operations increased in size, multi-sheaved blocks for rigging tackles became commonplace while the blocks themselves were often enlarged as well, some reaching more than a meter in length. In the centuries that followed, blocks did not exceed these dimensions until the late 19th century and the introduction of steel blocks for heavy-lift cranes.

Blocks from the Medieval and Renaissance Periods

Few wrecks containing preserved rigging blocks have been found from the centuries following the fall of the Roman Empire. Only one wreck, the Serçe Limanı vessel from the early 11th century, provides examples of medieval rigging blocks. The other ships from that era that have been excavated have not contained blocks. The Skuldelev Viking ships were sunk as channel barriers and were older, worn out vessels stripped of all useful equipment. The Gokstad and Oseberg Viking ships, despite being thoroughly rigged and fitted out for the voyage to the after life, also lacked blocks—raising questions about the accuracy of some of the replica rigs being sailed today. Despite the recovery of more than 20 of the enormous medieval cogs that carried the vast majority of the cargo moved during the period, none have contained any rigging gear (McGrail 2001:237). In fact, the best-preserved example, the Bremen Cog, was probably not even rigged when it was swept downriver from the shipyard and subsequently foundered (Steffy 1994:121). The Serçe Limanı vessel is thus the only published archaeological source of information on rigging blocks from this entire period.

The Serçe Limanı vessel was found off the southwestern coast of Turkey and excavated between 1977 and 1979 (Bass 2004:53-62). Being inside a sheltered cove, moderate sedimentation had covered and protected the wreckage, including three reasonably well-preserved rigging blocks. The largest is a treble block 350mm in length, 160mm wide, and 100mm thick and is published as RG1 (Figure 3.11). It is an all-wooden block with no trace of metal parts. It consists of only the one-piece shell, the three sheaves, axle, and a pair of mushroom-shaped bungs fitted over the ends of the axle (Mathews 2004:171). A large hole passing through the head of the block (as defined by the shape of the sheave mortises) perpendicular to the sheaves provided an attachment point for a pendant. Three smaller holes bored through the foot of the block (just off the end of the three sheave mortises and reminiscent of the holes in the County Hall block) served another unknown purpose. As the foot of a tackle block is positioned amidst the tackle falls, it cannot be affixed to a spar or load. The most likely function of these holes was to be a becket, securing the standing end of the fall. The presence of three holes, however, suggests that the standing end may have been un-laid into three strands to create a bridle or, perhaps, three separate tackles ran through this block, each needing a becket point. The latter interpretation, although sometimes seen aboard large sailing vessels of later eras, is unlikely to agree with any of the Byzantine rigging reconstructions done to date. The rigs simply did not require a block that would handle three separate tackles all running parallel to one another (essential for keeping a fairlead into the block; non-parallel lines require separate blocks to maintain fair leads).

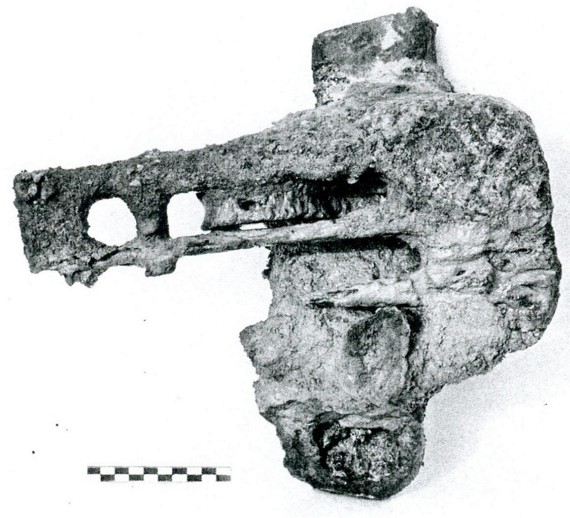


FIGURE 3.11. The treble block recovered from the Serçe Limanı site (Matthews 2001:171).

The second block found at Serçe Limanı, tagged RG2, is a single block with an almost perfectly rectangular shell. It measures just 200mm in length and, like RG1, was carved from a solid block of wood. Unfortunately, the sheave and axle are missing (Matthews 2001:172-174).

The third block, RG3, is an oblong cylinder with a slight diamond profile and a large cap on the top (Figure 3.12). The entire shell is carved from a single piece of wood. A deep strop score runs down the sides and passes through a hole bored through the foot of the block. The strop is then taken toward the head and passes through the cap, emerging from the top of the shell to be spliced or seized to itself. A small sheave rotated on a wooden axle pin (Matthews 2001:172-174). The entire block's form shows a clear refinement of blockmaking.

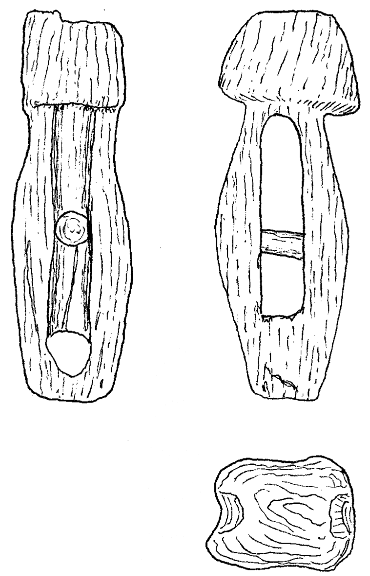


FIGURE 3.12. Remains of a single block from Serçe Limanı (Drawing by Nathaniel Howe, 2011 after Matthews 2001:Figure 11-5).

In addition to these three blocks, 15 block sheaves, a thimble, and a rigging toggle were also found (Matthews 2001:175-177). Most of the sheaves were severely decayed, but the quantity illustrates the growing complexity of ships' rigging in the 11th century.

Blocks From the Age of Discovery

Unfortunately, no blocks have been recovered from a vessel from the Age of Discovery. This is largely because so few vessels from this period have been found, excavated, or published. One notable exception is the Molasses Reef wreck. Small bronze cylinders were found in large numbers and later concluded to be bearings for block sheaves, the wooden sheaves themselves having been lost to decay long before (Fred Hocker, 2011, pers. comm.). If so, the Molasses Reef wreck is the oldest vessel to yield blocks with metal bearings. The bearings served to both reduce resistance and to extend the lifespan of the block. It is therefore also the first instance of metal parts being added to a block for increased efficiency, not just for strength. It is an unfortunate circumstance that more blocks from the Age of Exploration have not been recovered and published as major advances in block technology and the development of long-distance seafaring were occurring during that period, advances that are visible in the blocks of the 16th century.

Blocks of the 16th Century

Wreck sites from the 16th century are the oldest to yield large numbers of blocks. This is principally because ships of this era were markedly larger with much more complex rigs than ever before. The development of the galleon alone put ships to sea requiring several hundred blocks to manage their expanse of canvas. The two most significant 16th century block collections recovered to date come from *Mary Rose* and the Red Bay wrecks. The blocks found at these sites will be discussed in detail later in this thesis as they predate *Vasa* by less than a century, but several important generalizations regarding block development as shown in these collection are worthy of brief discussion at this juncture.

The Basque whaler found at Red Bay is known as site 24M, but it is surmised that it may be the whaling galleon *San Juan*, reported lost in those waters in 1565 (Bradley 2007:IV-10). In all, 426 items from the ship's rigging were recovered during the eight seasons of diving conducted on the wreck. The bulk of these items consist of hearts, parrel trucks, deadeyes, toggles, and six types of cordage appearing in short lengths all over the wreck site (Bradley 2007:IV-1 to IV-23).

Two major block types were found at 24M. The largest group consists of 16 single blocks (Figure 3.13). These are of all-wooden construction and are very rectangular in form, but with broadly chamfered edges. As seen in the Serçe Limanı blocks, the strop scores tunnel through the head of the block and emerge out the top. The foot of these blocks, however, has a deep strop score around the heel rather than a hole bored through the foot. There is no trace of metal fittings on any of these blocks (Bradley 2007:IV-11).

The second type of block recovered from the 24M site consists of six elongated double blocks, with the two sheaves set end to end (Figure 3.13). The arrangement matches that of a typical fiddle block, with the upper sheave being larger in diameter to prevent chafing and binding in the tackle falls. Yet, these blocks lack the distinctive figure-of-eight or fiddle shape seen on ships elsewhere in Europe between the 17th and 20th centuries. More significantly, these blocks were not stropped. Instead, they were secured with a pendant fastened to the head of the block (Bradley 2007:IV-13-IV-17). This configuration likely made them more prone to splitting as they lacked the support provided by a full, encompassing strop.

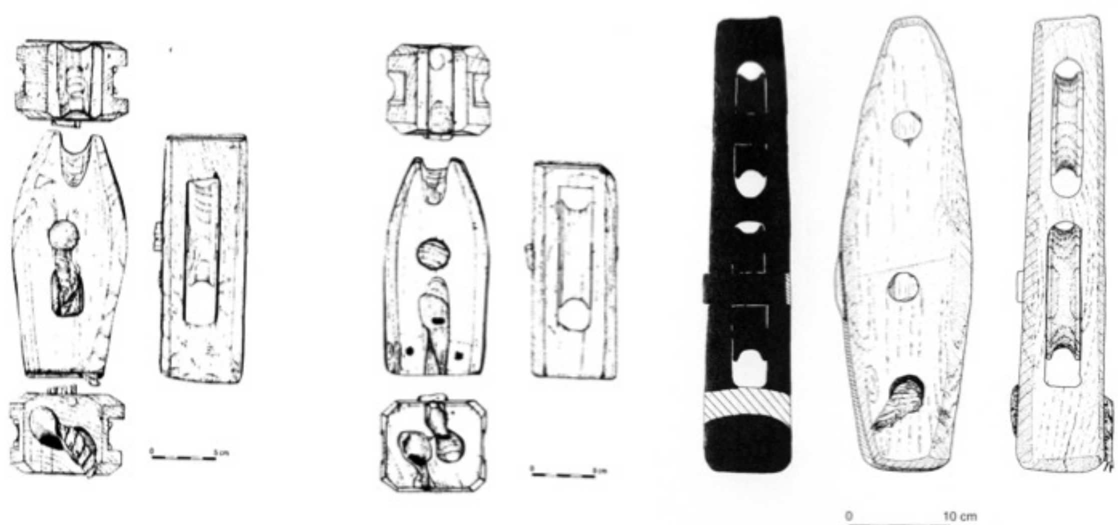


FIGURE 3.13. Single blocks and the non-stropped long tackle blocks from the 24M site in Red Bay (Bradley 2004:Figures 17.1.18, 17.1.19, and 17.1.25a).

The second major collection of 16th century blocks comes from the English warship *Mary Rose* (Figure 3.14). Caught broadside by a gust, the top-heavy warship heeled over, flooded, and sank into the muddy channel bottom at the entrance to the Solent in 1545. *Mary Rose* was fitted with an assortment of block types ranging considerably in size and form. Many of these were built with bearings or entire sheaves made of bronze; this was a major development in block construction.

The single blocks include a type that is roughly pear-shaped with a flat top. Like the 24M blocks, the strop scores tunnel through the head of the block and the edges of the shell are chamfered. These are all-wooden blocks cut from elm (Marsden 2007:263). A second type of single block is a large, rectangular snatch block, having an open swallow for laying in or lifting out the fall. This block was also made entirely of wood and has a large pendant hole in the head for securing it (Marsden 2007:267). A third type of single block is somewhat triangular, the broad base being at the head. It is rectangular in cross-section and features crisply chamfered corners and a bronze sheave (Marsden 2007:269). A fourth type of single block features a large cap at both ends of the block. A deep strop score is sunk into the foot of the block while it passes through tunnels in the head. This block type is also of all wooden construction (Marsden 2007: 264). Illustrating the longevity of the block's simple technology, this block type is almost identical to one of the single blocks recovered from the Serçe Limanı*,* launched more than 500 years earlier (Bass et al 2005:106 & Marsden 2009:264).

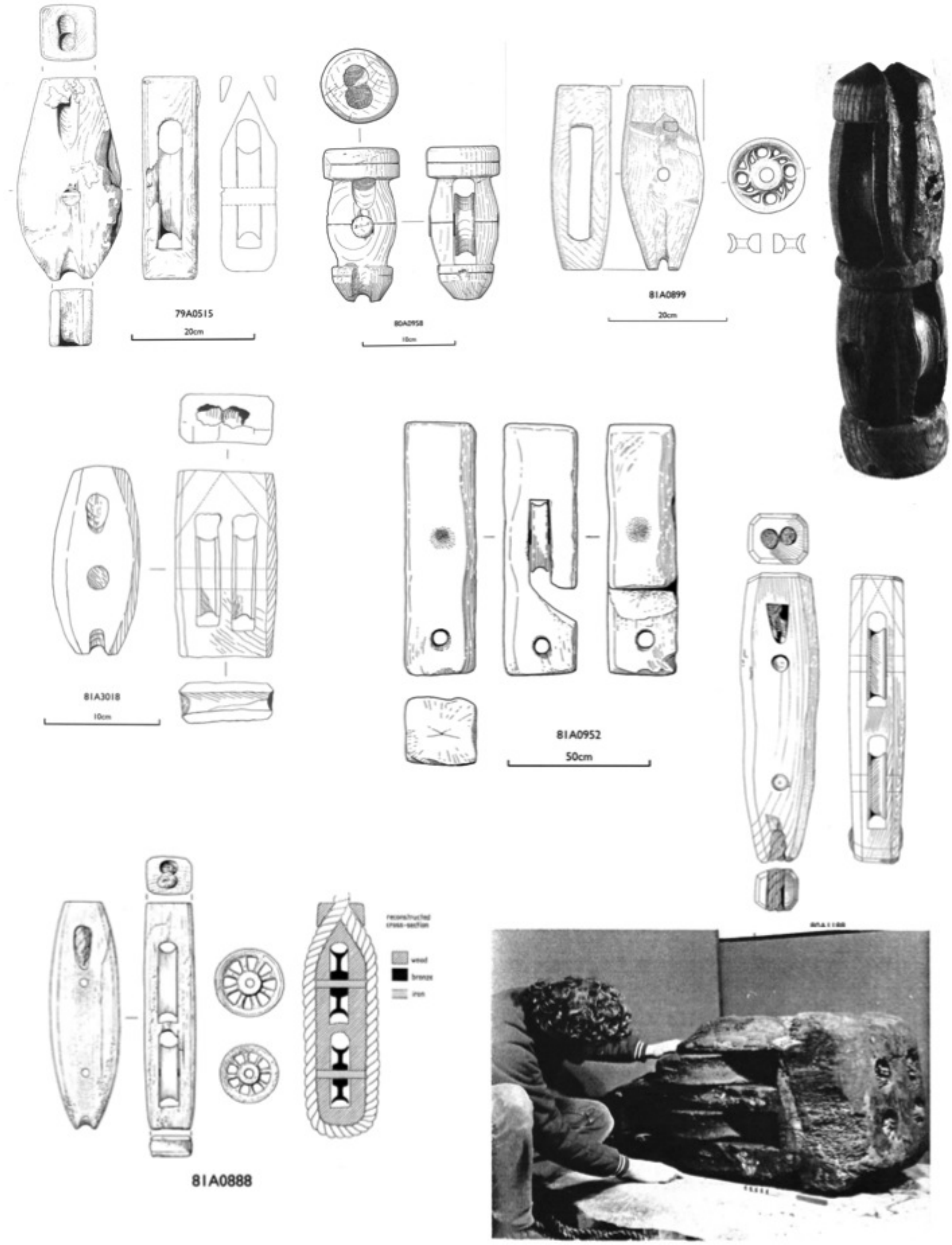


FIGURE 3.14. Rigging blocks recovered from the English warship *Mary Rose* (photos from Rule 1982:140,143; drawings from Marsden 2009:263-269).

Mary Rose also yielded several long tackle blocks similar to those found at the 24M site, although the *Mary Rose* examples are fully stropped and they are more refined in their geometry. Most of these blocks are of all wooden construction, but some held cast bronze sheaves and iron axles intended for handling particularly heavy loads. Some of the long tackle blocks carried two wooden sheaves of equal size (Marsden 2009:265, 267) and would therefore have been prone to chafing the cordage and possibly binding up when hauled chock-a-block.

An all-wooden sister block with two sheaves of equal size set end-to-end, but turned 90° to one another along the longitudinal axis of the block was found as well. This block has carved caps at head and foot and a smaller collar between the sheave mortises. The strop wraps around a score in the heel and tunnels through the cap at the head (Rule 1982:140).

A type of double block with side-by-side sheaves set on a single axle was also recovered. This type was made of all wooden construction and had a strop that passed through tunnels in the head of the block like the others (Marsden 2009:266). A second side-by-side double block more than a meter in length was also recovered. This example is the only block that is double-stropped, having four holes bored through the head to center the strops. It has wooden sheaves, but most likely an iron axle (Rule 1982:143).

The blocks recovered with *Mary Rose* demonstrate riggers' ongoing innovation in block design. The ship carried more specialized block types than earlier vessels, a fact reflective of the growing complexity of ships' rigging in the 16th century. *Mary Rose*'s rigging blocks also incorporate internal metal fittings. Bronze sheaves, not seen in blocks from earlier vessels, appear frequently among *Mary Rose*'s blocks.

The Development of Blocks in Review

Examining the archaeological evidence from all of these sites shows that blocks have been employed in seafaring since at least the Greek Classical period. The examples recovered at Kyrenia, Lake Nemi, Kenchreai, and other ancient sites include simplistic single blocks as well as remarkably refined and complex multi-sheaved blocks, indicating that block technology was already highly developed before the birth of Christ. Since the first millennium B.C., numerous cultures have improved block technology by adding protective casings, multiple sheaves, rigging blocks in tackles as Archimedes had done, or using new materials such as the bronze sheaves found on *Mary Rose*. Yet in some parts of the world, blocks maintained their earlier forms. The traditional craft of the Malay Peninsula and Indonesia continued to use a very basic block with no pulley well into the 20th century and some vernacular watercraft traditions such as the Fijian outrigger canoe never developed blocks at all (Marquardt 1992:161-165).

Chapter 4. The Physics of Blocks

Introduction

The important role of rigging blocks in the development and operation of large sailing vessels is rooted in the fundamental functions blocks provide; the ability to efficiently redirect or multiply pulling forces. This chapter examines the physical mechanics governing these two operations and the structural requirements blocks must meet in order to provide reliable shipboard service. As mechanical devices, functional performance is the sole and uncompromising judge of quality.

Resistance Reduction

A block's defining characteristic is its ability to allow a line to pass around a sharp bend with minimal resistance. The mechanics involved in this operation are relatively simple and can be explained through Isaac Newton's laws of motion and the laws of friction postulated by Guillaume Amontons and Charles Augustin Coulomb (Cotterell and Kamminga 1990:92). In physical function, a block sheave is no different than a pulley and the physics are exactly the same. Blocks simply acquired another name from their cultural context (the French term for a block, however, is still *pullie*). Although explanations of pulleys can be found in almost every introductory engineering textbook, such explanations typically bypass the physical principals of the pulley itself and proceed directly to compound systems (tackles) without covering the mechanics of resistance reduction that pulleys perform (e.g. Boyd 1921). The physical mechanics by which a block sheave minimizes resistance is more easily conceptualized as a pair of actions performed by the sheave. The first action is to transmit kinetic energy and friction to other components. The second action is to impart a mechanical advantage over that friction using the sheave's radius as a lever. These two actions both contribute to reducing resistance.

These mechanical operations occur as an interaction between the sheave, axle, and fall. For the present, the shell can be ignored. While it certainly does serve an important role by holding the sheave and axle in place, it is not a component of the physical principals involved in resistance reduction.

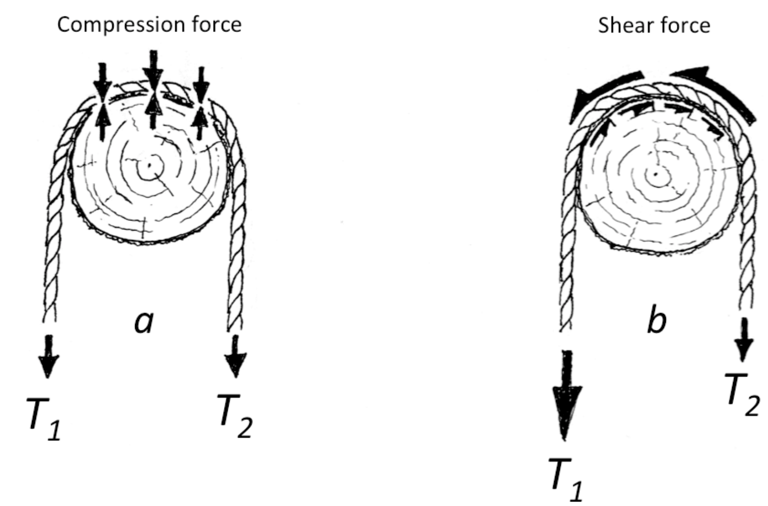


FIGURE 4.1. Force diagram showing relative tensions of a line thrown over a tree limb when (*a*) at rest with equal tension in both legs of the cordage and (*b*) in motion or about to go into motion due to unequal tension in the two legs of the cordage. The compression force in example (*a*) is present as long as there is tension in the line pulling it against the limb. The limb resists this force as described by Newton's Second Law with an equal and opposite reactive force. This pressure creates friction to resist movement of the line when the line is pulled as in example (*b*). The opposing tension and friction forces create a shear force described by the equation $F_{shear} = T_1 - (F_{friction} + T_2)$ (Diagram by Nathaniel Howe, 2011).

To explain the block sheave's function, it is important to first consider a situation without a sheave. A line is thrown over a tree limb and equal force applied to both ends (*a* in Figure 4.1). The combined load exerts a downward force on the top of the limb. Exemplifying Newton's third law of motion, the stationary limb exerts an equal and opposite force upward against the line. The net force is zero so the line and limb remain at rest, but the opposing forces create and maintain pressure between the two objects. If one end of the line is then hauled upon (*b* in figure 4.1) it will create an imbalance in tension within the cordage and induce the line to go into motion as described by Newton's second law. This motion, however, is opposed by friction between the line and the tree limb. The friction is generated by the pressure holding them in contact (pressure created by the downward force of the line and the reactive upward force of the limb). Assuming that the friction created by this pressure and the shear force exerted by the cordage cannot tear the limb away from the tree trunk, the limb will remain stationary and serve as a fixed point. The line must slide around the limb. It is made of flexible cordage and can therefore only exert force as tension in the direction of its length, but its flexibility allows it to exert that tension force around corners (Boyd 1921:31). The line passes the pulling force over the limb, to haul the trailing end around the obstacle. At first, the friction resisting it is static while the pulling force builds. Then the static friction is overcome by the pulling force and the line actually begins to move. At this point static friction (also called limiting friction) is replaced by kinetic friction, which for most materials has a slightly lower friction constant (Nelson et al 1998:127). Both kinds of friction may be increased by roughness in the line or the tree bark at the contact interface. The combined friction force can be very strong. It is possible to expend the entire available pulling force trying to overcome the static friction. In some cases, tension can even be increased until it exceeds the tensile strength of the cordage without ever overcoming the static friction. It was friction forces approaching these limits that created the need for blocks on ancient ships. More men and heavier cordage were not ideal solutions for overcoming high resistance. Minimizing the effort required to fight such resistance was one of the chief reasons blocks were incorporated into ships' rigging.

Replacing the tree limb with a block sheave mounted on an axle alters the mechanical relationship. The essential difference is the sheave's ability to rotate. Instead of resisting movement, the sheave can move with the line. When one end of the line is hauled upon, the static friction between the line and the sheave transfer some kinetic energy to the sheave and cause it to move concurrently with the line. Mounted on an axle and acted upon at multiple angles by the cordage wrapped around a portion of its circumference, the sheave is induced to move in a circular motion. For the kinetic energy to transfer from the line to the sheave, the static friction between the line and the sheave must exceed the static friction between the sheave and axle. A sheave-axle bearing clotted with grit (high friction), or conversely, a line with very smooth strands or a very light load on it (low friction), will not make the sheave rotate. Instead, the line will continue to slide over the sheave as on the tree limb. A sheave in good condition, however, will effectively use the static friction at the line-sheave interface to transmit kinetic energy to the sheave and transfer the area of kinetic friction from the line-sheave interface to the area of contact between the sheave and axle. This transfer of kinetic friction has two immediate advantages. First, the mating surfaces of the sheave and axle can be made much smoother and less elastic than cordage, reducing the amount of friction introduced by the surface texture. Second, transferring the kinetic friction reduces wear and abrasion. Cordage is generally less durable than the materials used to make axles and sheaves and its comparative roughness would exacerbate abrasion from kinetic friction. Transferring the area of kinetic friction to harder and smoother components thereby improves the efficiency of the block and prolongs its functional lifespan.

This transfer of kinetic energy and friction, however, is not the principal mechanism by which a block sheave allows a line to pass around a sharp bend with minimal resistance. The operative mechanical action concerns the leverage obtained from the relative diameters of the sheave and axle. As described, the sheave reduces friction by mating surfaces and materials with lower friction constants. It also concentrates the area of kinetic friction, focusing it on the upper portion of the axle. This in itself does not alter the friction force. Guillaume Amontons' second law of friction observes that a friction force is independent of the area of contact—presuming that the surfaces are rigid and inelastic (Heyman 1972:76; Levinson 1961:107). This is because concentrating the area of contact also concentrates the force of the load, increasing pressure at the contact interface between the axle and sheave and thereby maintaining a constant friction force. The importance of concentrating the friction on the axle is that it establishes a distance (d_1 in Figure 4.2) between the *action* where kinetic energy enters the system through tension in the cordage and the *reaction* where kinetic energy is resisted by friction at the axle. This distance constitutes a lever with the center of the axle as its fulcrum.

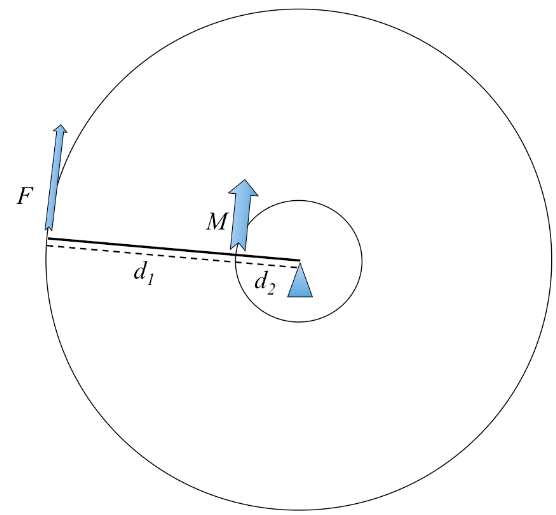


FIGURE 4.2. The radius of the sheave creates a lever that provides mechanical advantage over friction at the axle. This lever is a second order lever with the load and the effort being on the same side of the fulcrum (Diagram by Nathaniel Howe, 2011).

As defined in the equation for second order levers (those with the load and the effort on the same side of the fulcrum), the mechanical relationship between the force of effort and the force of static friction in a block sheave can be represented by the equation

$$F_e = M\,(d_1)(d_2)$$

where F_e is the force required to overcome the static friction, M is the moment equal and opposite to the force of static friction, d_1 is the length of the lever arm (equal to the sheave radius minus the axle radius), and d_2 is the distance between the load and the fulcrum (radius of the axle). Consequently, a greater ratio between the sheave and axle diameters yields a greater mechanical advantage.

The leverage obtained from a block sheave is continuous. The circular form and rotational motion of the sheave allow it to act as an infinite series of levers radiating out to the sheave's circumference (Figure 4.3). This allows the sheave to provide a constant mechanical advantage over friction throughout an entire revolution and continue to do so for an infinite number of revolutions.

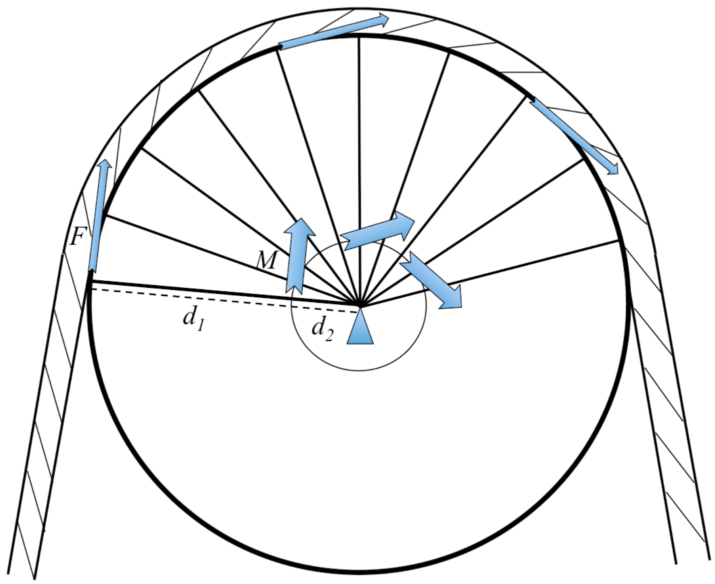


FIGURE 4.3. The sheave functions as a series of radial lever arms, providing continuous mechanical advantage as the sheave rotates (Diagram by Nathaniel Howe, 2011).

Through this continuous internal lever action, a block by itself does actually provide mechanical advantage. The advantage, however, is over friction at the point where the cordage changes direction, not over the load carried by the fall. This is a critical distinction as blocks are often erroneously defined as being devices used to “increase the purchase” (Biddlecombe 1848:3). In actual fact, it is only when rigged together in tackles that blocks provide a mechanical advantage over the load. A block by itself only provides a mechanical advantage over internal friction. Yet this localized advantage has the far-reaching effect of minimizing the overall resistance of the block and making tackles and complex rigs possible and making general ship handling easier.

Tackles

The ability to efficiently redirect pulling forces with minimal resistance enables blocks to serve a second major shipboard function—multiplying pulling forces. Blocks can provide this mechanical advantage when rigged together to form tackles (Figure 4.4). Tackles—also known as compound pulleys—are simple machines using block technology applied in a series to obtain a mechanical advantage. They consist of at least two blocks that are rove together with a single fall passing between them at least twice (or between their mountings as in tackle *c,* Figure 4.4). This forms a two-part tackle. Six- and eight-part tackles are not uncommon. Tackles have been used on land and at sea for more than 2,200 years. Archimedes is often credited with the invention of the tackle, but there is substantial evidence that Aristotle was fully familiar with their function a century earlier (Cotterell and Kamminga 1990:90). Their usefulness aboard ships cannot be understated. Even a four-part tackle provides a ship's crew with an enormous mechanical advantage of almost 4:1. When trying to control an angry sail in a violent squall, the ability to add a three-fold increase to each man's strength has an enormous impact on ship handling.

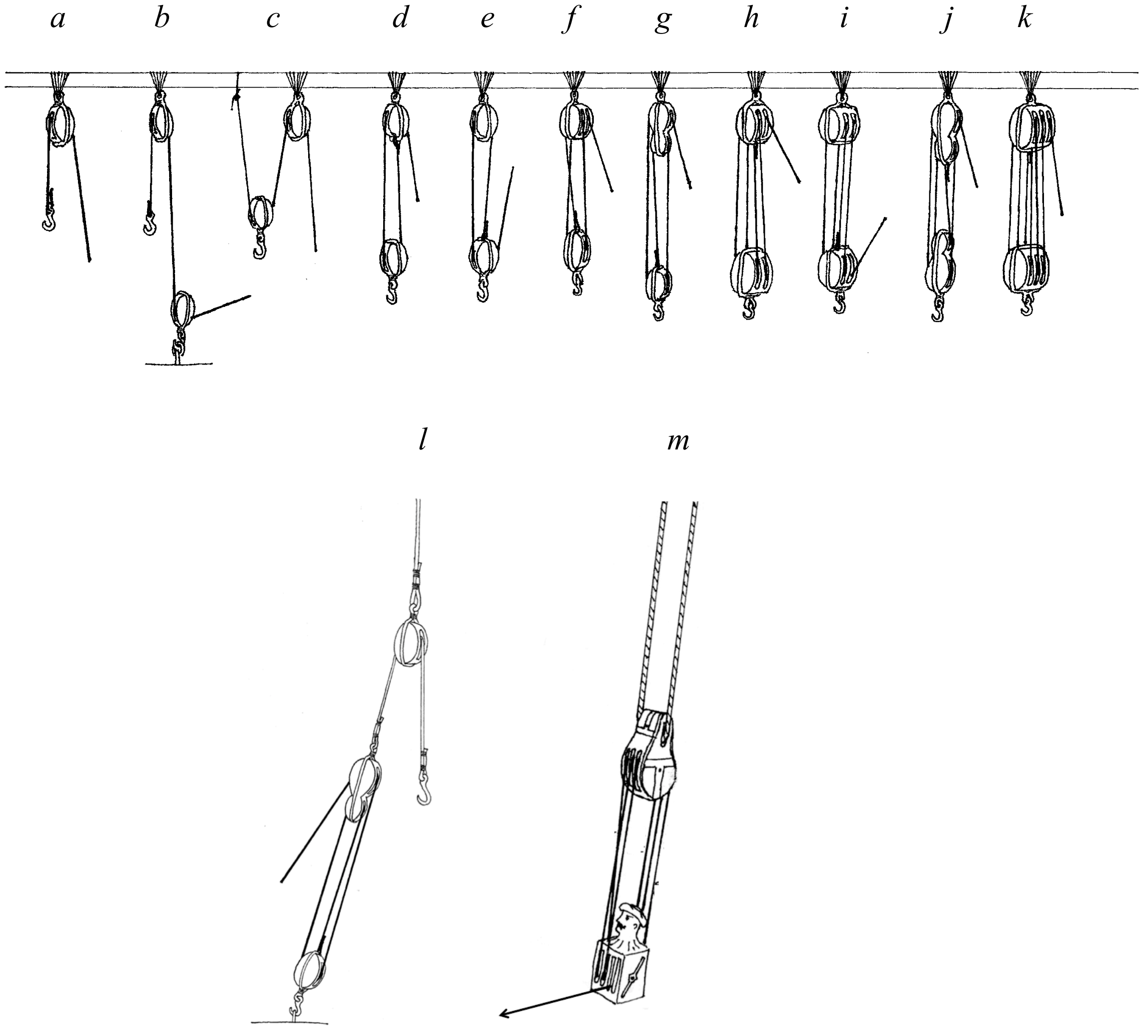


FIGURE 4.4. An assortment of tackle arrangements often seen on ships for multiplying pulling forces at a mechanical advantage; (a) a single whip (b) a single whip with a lead block, or foot block (c) a double whip or whip with a running block (d) gun tackle purchase (e) inverted gun tackle purchase (f) luff tackle or watch tackle (g) luff tackle rigged with a fiddle block or top burton tackle (h) double luff tackle purchase (i) inverted double luff tackle purchase (j) long tackle or Dutch backstay tackle (k) 6-part tackle (l) whip and tackle, garnet tackle, or runner tackle (m) 6-part halyard tackle rigged between a knighthead and a ram's head block (Drawings by Nathaniel Howe, 2011).

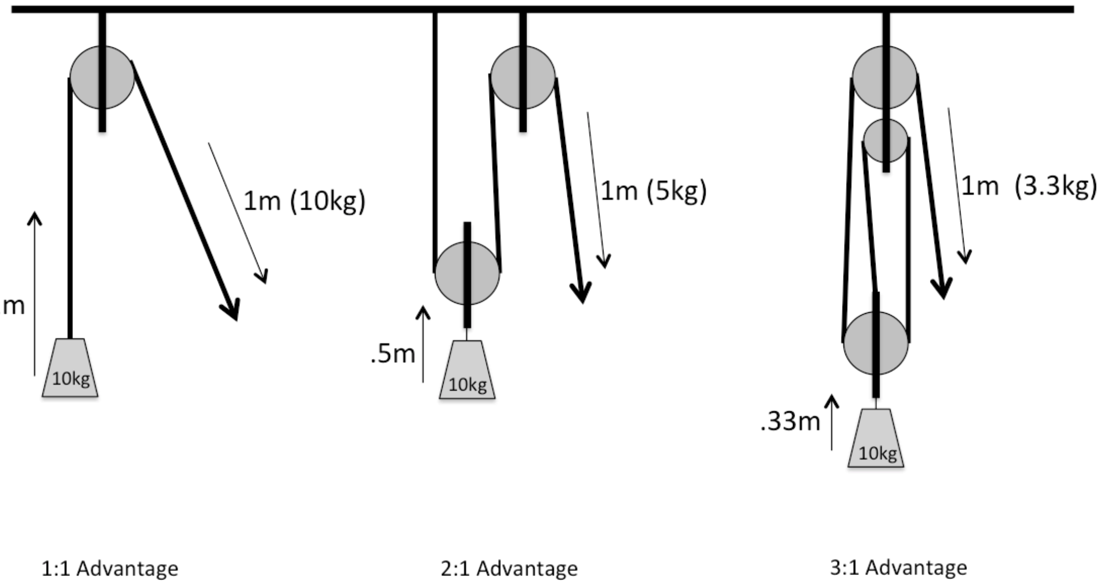


FIGURE 4.5. Tackle mechanics. Each of these three tackles is lifting a 10kg load and has the working end pulled 1 meter. Depending on the power of the tackle ("power" is determined by the number of legs supporting the load), length of pull is exchanged for mechanical advantage. Thus, in the third example, pulling 1 meter of line on the working end moves the load only .33m, but the force required on the working end is just 3.3kg. This tackle therefore has a 3:1 advantage (Diagram by Nathaniel Howe, 2011).

The physical mechanics governing the operation of tackles consists of two key mechanical principles: load distribution and the aforementioned resistance reduction of pulleys. These two principles acting in concert are the basis of the tackle as a simple machine. The easiest way to conceptualize the mechanical function of a tackle is to consider the examples shown in Figure 4.5.

The first configuration consisting of a single block and 10kg weight on the standing end of the fall is not actually a tackle at all. By definition, two blocks are required for a tackle. This arrangement is termed a whip. Its mechanical advantage is 1:1, or more clearly stated, it offers no advantage at all. Pulling one meter on the working end will require 10kg of force and will raise the weight one meter.

In the second example, two blocks are rigged together such that two legs of the fall are directly supporting the load. The reduced resistance at each turn of the fall due to the resistance reduction mechanics of the block sheaves allows the tension to balance throughout the fall. This means that the two legs of the fall supporting the lower block and the 10kg weight will carry an equal fraction of the total load—in this case, one-half. Assuming that friction is negligible, this places 5kg of strain on each leg. The upper block also equalizes the tension in the fall, passing the strain along to the working end as well. Holding the working end will therefore require 5kg of force—half the load. The mechanical advantage is thus 2:1. To obtain such an advantage, however, length of pull has been sacrificed. Like the strain of the load, the length of pull on the working end is also divided equally between the two legs of the fall directly supporting the load. Therefore a one-meter pull on the working end will raise the load only half a meter.

In the third example a double block (fiddle type) and a single block are rove together. There are three legs of the fall directly supporting the load so the strain will be evenly divided among these legs, reducing the tension in the cordage to one-third of the original load. This yields a mechanical advantage of 3:1, requiring only 3.3kg of force to hold the working end. In exchange for this advantage, a 1-meter pull on the working end will only raise the load .33 meters.

Extrapolating from these examples, the force required to hold the working end of a tackle fall is a fraction of the total force exerted by the load equal to one divided by the number of cords directly supporting the load. This can be represented by the equation

$$F_w = \frac{1}{C}$$

where F_w is the force or tension required at the working end to keep the system at rest and C is the number of cords directly supporting the load. Note that the working end is *not* counted as one of the cords unless it directly supports the load as in tackles (*e*) and (*i*) in Figure 4.4. The fraction of the load carried by each cord is the inverse of the mechanical advantage obtained by the tackle. If the tackle reduces the tension on the working end to one-quarter of the total load, then the mechanical advantage is 4:1. In tackle (*g*), the advantage is 3:1. No tackle, however, is efficient enough to actually provide its full, theoretical advantage. The reason is that blocks are not 100% efficient and while they can certainly minimize resistance when passing a line around a sharp bend, they cannot eliminate it. Friction between the sheave and the axle is one factor. This can be represented by the equation

$$F_f = \mu F_p$$

where F_f is the force of friction, μ is the friction constant (static or kinetic), and F_p is the normal force, or rather, the force of the load being transmitted from the sheave to the axle (Levinson 1961:107; Nelson et al 1998:127). Note that as observed in Amontons' second law of friction, surface area is not a factor in calculating friction. Modifying that equation to include leverage (F_l),

$$F_l > \mu F_p$$

demonstrates that the leverage must be greater than the friction between the sheave and the axle in order for the sheave to turn. Increasing the surface friction constant or the load on the system will increase friction and require greater leverage to overcome. Assuming sheave diameter is constant, more force must be applied to initiate motion. This friction calculation accounts for just one sheave. Every turn around a block sheave will absorb some of the pulling force and reduce the efficiency of the tackle.

Friction at the axle, however, is not the only force opposing the smooth operation of a block in passing a line around a sharp bend. The cordage itself can contribute a significant frictional force. Chafing against the block shell certainly increases resistance, but so does internal friction within the cordage. Despite being known for its inherent flexibility, all cordage has some degree of rigidity and will resist bending. This resistance is created by the internal mechanics of rope and the interaction of the individual fibers, bound together by friction and collectively resisting both tension and compression as the line is forced into a bend. In daily operations at sea, the resistance created by cordage rigidity is only apparent in especially heavy hawsers or when taking a heavy line around a small cleat or block. Yet even relatively light and flexible cordage can impart a significant frictional force impacting the efficiency of rigging blocks—particularly in tackles where the line is forced into numerous 180° turns.

Early studies on the mechanics of cordage rigidity and its effect on rigging efficiency were conducted for the French Navy by Charles Augustin Coulomb in the 1780s. His work on this subject has largely been overshadowed by his general theories on friction. In the late 19th century, the American engineer, Augustus Du Bois, published on the topic as well (Cotterell and Kamminga 1990:92). Du Bois provides a formula for determining the internal friction of new hemp cordage rove over sheaves of a known size,

$$dT_r = \frac{900 + 3.3T}{D+a}$$

where T is the tension in the line measured in newtons, D is the diameter of the sheave in millimeters, and a is the diameter of the cordage in millimeters (Cotterell and Kamminga

1990:92). Note that sheave diameter is a crucial factor as it controls how sharply the line must make the turn. This formula yields only the resistance of the line to bending around one sheave. To determine the total friction on a compound system requires this figure to be multiplied by the number of sheaves and then add any other resistance factors (such as sheave-axle friction). The percentage of the total force applied to the working end that must be expended on forcing a line around one or more block sheaves varies widely depending on the stiffness of the cordage (dictated by age, material, and fiber size), the number of changes in direction at block sheaves, the diameter of the sheaves, and the size of the total load on the cordage. Depending on these factors, efficiency can range from 0% to almost 100%. With heavy enough cordage or too many block sheaves, resistance can climb until it negates all mechanical advantage and may even ascend to the point of absorbing all of the pulling effort and preventing any movement of the fall.

This is why tackle blocks of more than three sheaves are extremely rare. In cases where more purchase is needed, it is often more efficient to rig two tackles in parallel using lighter, more flexible cordage or to combine a tackle with another simple machine such as a windlass (Cotterell and Kamminga 1990:93). Although stiff cordage, too many turns around block sheaves, and axle friction can be significantly reduce the efficiency of a tackle, the leverage obtained over friction by the individual block sheaves is the essential difference between a multi-part tackle and a lashing. The run of the cordage is essentially the same in both cases, but the rotating sheaves allowing the fall to pass freely around all the sharp turns in a tackle make it possible to transform a tight binding into a moving simple machine that can provide vital mechanical advantage for sailors and serve innumerable applications aboard ship.

Internal Engineering of Blocks

In the rig of a large sailing ship, even the smallest blocks must frequently handle enormous loads. To prevent them from shattering or binding—failures that could paralyze a portion of the rig—blocks must be made with quality materials and close attention to grain, symmetry, and clearances. For particularly demanding applications, specially engineered blocks are sometimes necessary. This is particularly true in *Vasa*'s era when blocks were still all-wooden devices, often pressed to the load-limit of wooden construction.

Force is primarily applied to a block by the strop and the cordage running through it—a medium with some remarkable physical properties of its own. Unlike most materials, the inherent flexibility of cordage permits the exertion of tension forces, but not compression forces. The advantage of this property, however, is that it does permit the direction of a pulling force to be altered by simply bending the line around a fixed point—the purpose for which the block was developed. The fixed point opposes the natural tendency of cordage to straighten out between its sources of tension when drawn taut by a pulling force applied to one or both ends. Consequently, the two legs of the fall exert a combined pulling force on the block. Opposing this force is the strop or pendant that anchors the blocks by the head. The block is therefore effectively strung between two opposing pulling forces. One comes from the two legs of the cordage running through it and the other from the strop or pendant. For blocks secured with pendants, these two pulling forces haul on the ends of the block applying a tension force to the shell. Inside blocks encompassed by a strop, however, these pulling forces overlap to form a shear load on the axle and a compression force on the shell. The two systems pulling on the block pass around each other and act on the opposite ends of the block. The fall pulls the middle of the block towards the foot and presses it into the strop while the strop pulls the foot toward the head (Figure 4.6). For most blocks, the load transfer path between the two systems runs through the lower portion block, requiring each element therein—the sheave, axle, and shell—to be capable of absorbing the entire load.

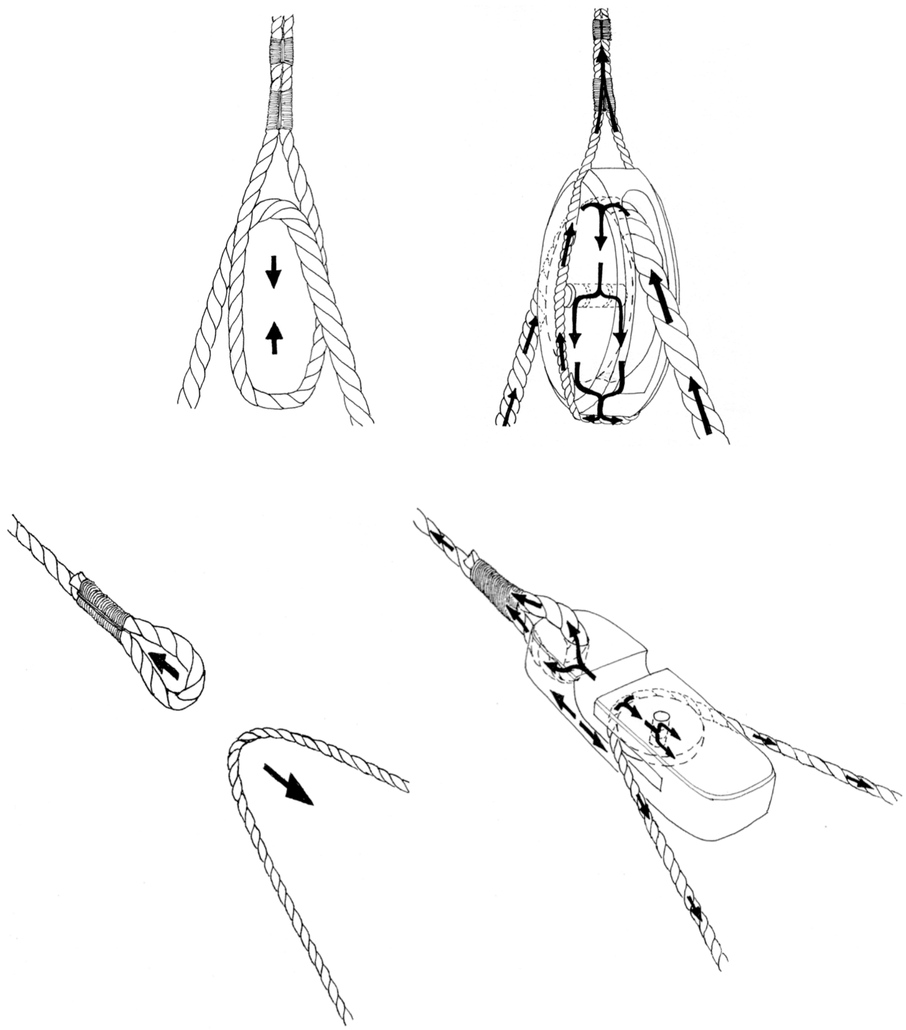


FIGURE 4.6. Force diagrams showing the load exerted by the cordage and its transfer path through a stopped block, then through a pendant block. In both cases, the entire load passes through each of the block's three principal elements. The shell, axle, and sheave all must be constructed to withstand the entire load. In contrast, the shell of the stropped blocks must withstand an overall compression force while the pendant block must withstand a tension force (Drawings by Nathaniel Howe, 2011).

Under particularly heavy loads it was not uncommon for wooden blocks to bind up or split. To prevent this, blocks rigged in positions that were known to come under particularly heavy strains were often engineered for heavier loads. Thicker cheeks, double strops, multiple sheaves, or iron strops were common adaptations. The wide diversity of block types seen during the Age of Sail is primarily rooted in the equally diverse range of functions blocks had to perform aboard ship and the associated variability in physical requirements. In each case, the form and construction of the block was dictated by the physical demands placed upon it.

Vasa's blocks, for example, show a number of modifications for meeting specialized physical requirements. A handful exhibit abnormally thick shells, nearly a dozen were rigged for iron strops, and a few of the largest blocks even had iron sheaves and axles. The selection of more resilient materials for certain blocks is apparent in the choice of wood species as well. Although many of *Vasa*'s blocks are oak, the vast majority of the rigging blocks are ash. Oak is a very strong wood and can stand up to considerable force for prolonged periods, but ash is slightly more resilient to shock forces. For blocks suspended in the rig and likely to strike hard against the ship's spars, such resilience was a particularly important quality.

A few common causes for structural failure of a block could be avoided by good design. Shell failure was perhaps the most common problem. The large, hollowed out wooden construction of a 17th-century block shell made it prone to cracking or splitting along the grain (Figure 4.7). This danger could be exaggerated if the axle was too narrow, placing too much pressure on the end grain at the axle hole and causing the axle to cleave downward through the cheeks and split the shell. More often, the block simply split across foot, especially if it was cut without close attention to the grain direction.

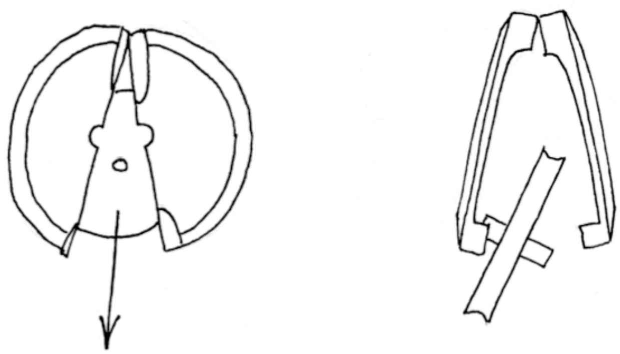


FIGURE 4.7. Block shells tend to split along the grain at the axle hole or across the head and foot (Drawing by Nathaniel Howe, 2011).

Sheave failure was another fairly common way for a block to break. *Vasa*'s block sheaves are cut with very close attention to grain direction, making use of fiber length and heartwood curvature to reduce the chances of splitting. If the sheave were to split, however, it would result in a serious jam that would paralyze the fall and possibly the sail or spar it was intended to control. Splitting along the growth rings, the sheave would acquire a wedge-shaped edge that would pinch the fall and jam it tightly against the shell (Figure 4.8). Alternatively, if the sheave split down the middle through the axle hole, the sheave would fall away in two pieces and the block would continue to function as a dead block, albeit with more resistance. In the centuries after *Vasa*, ash sheaves were largely replaced by *lignum vitae* sheaves that were cut across the grain. Although the short fiber lengths in these sheaves theoretically made them more prone to splitting, if split they would not form the wedge-shaped edge that would jam a line as in *Vasa*'s blocks. Instead, a split would simply take a chip out of the circumference and create a rough-running block (Figure 4.9).

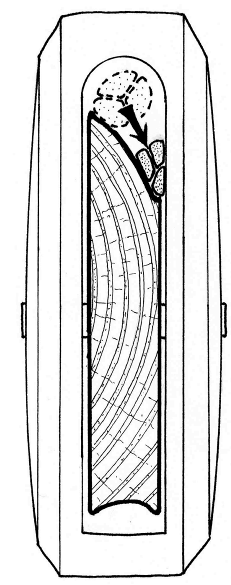


FIGURE 4.8. A sheave, if split along the grain, would pinch the fall against the mortise wall (Drawing by Nathaniel Howe, 2011).

FIGURE 4.9. A chipped *lignum vitae* block sheave. The principal difference in breakage along the grain as compared to the ash sheave is that this will not significantly impact the performance of the sheave (Photo courtesy of Vasamuseet).

Failure of the wood under a load was not the only way blocks could bind up or jam. Warped sheaves, crooked axles, or incompatible dimensions were all equally common causes. Consequently, blocks had to be made with a high level of precision and, on larger ships with complex rigging, also had to adhere to some basic standardization. In fact, blocks and cordage were probably one of the first aspects of ship design and construction to be standardized, strictly for the purpose of preventing jams.

This standardization focused on a few key features. It started with cordage. Complex rigs requiring large quantities of mass-produced cordage and interchangeable rigging hardware were adapted to standardized cordage sizes being produced by ropewalks. Accordingly, the swallows of the blocks made for *Vasa* had to be wide enough to admit that cordage with a little extra room for bloated, wet lines or frayed fibers. Although erosion has made it hard to determine exactly what the standard diameters were, there are at least 12 major swallow sizes present in the collection.

Standardized cordage sizes running through blocks with matched swallows dictate the thickness and diameter of the sheaves. A sheave that is significantly narrower than the sheave mortise creates a gap that the line can become caught in, especially if the cords or yarns are loosely laid (Figure 4.10). Conversely, if the sheave is too thick it will chafe and bind in the sheave mortise.

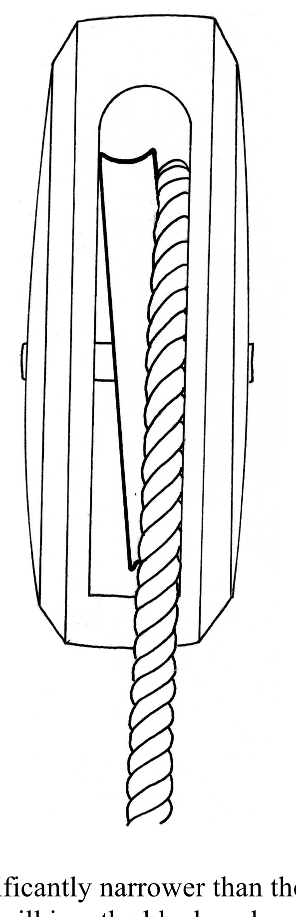


FIGURE 4.10. A sheave that is significantly narrower than the sheave mortise creates a gap that the line can become caught in. This will jam the block and paralyze the line. (Drawing by Nathaniel Howe, 2011).

The diameter of the sheave is important too. If it is too small, the fall will be forced to turn too sharply. A thick line cannot make such a bend. Under smaller loads, it will project off of the sheave and naturally form a gentler curve (Figure 4.11). This will permit the line to twist or kink more easily and cause more chafing on the block shell to either side of the swallow. Under heavier loads the fall will be forced tightly around the sheave, the sharp bend severely weakening the fall as the load is redistributed from all the fibers in the line to just those stretched taut around the outside of the curve. This will make the line prone to snapping and make the sharp turn at the block sheave act as a cutting point. Even if the line endures this load imbalance, the sharp turn will chafe the fibers against each other, causing abrasion that will weaken the line over time. Fortunately, a sheave diameter that is too large causes no damage.

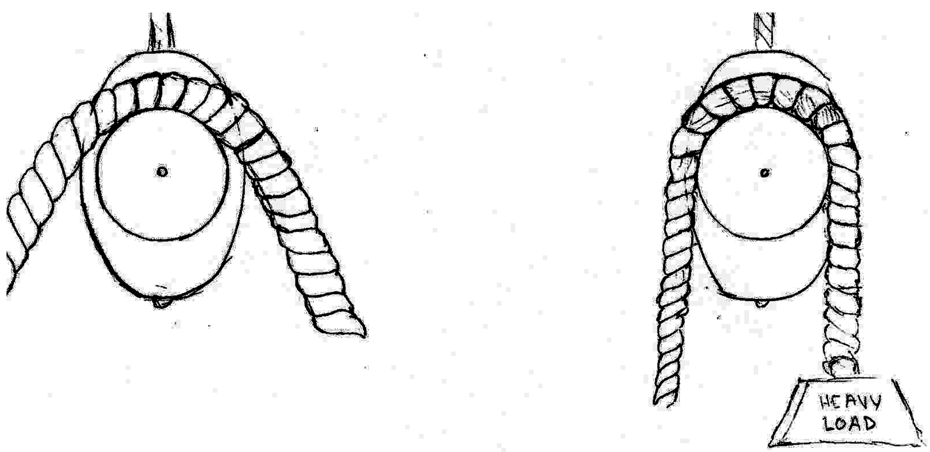


FIGURE 4.11. Effects of an undersized sheave when the fall is slack and when it is under a load. Note the unequal stretch and compression in the fall as it passes over the sheave. (Drawing by Nathaniel Howe, 2010).

A sheave must also be as perfectly balanced and as circular as possible. If it is oval in shape or if the axle is not centered, the sheave will rotate eccentrically, creating a fluctuation in the force and leverage required to rotate the sheave (Figure 4.12). That fluctuation is then transmitted to the fall, creating a jerking motion in the line that may create momentary pulling forces exceeding the capacity of the cordage, a fastening at the standing end, or the strength of those handling the working end.

All of these potential weak points in the smooth operation of a block can have serious consequences for the ship as a whole, particularly in confined waters where maintaining control and maneuverability is critical. The blockmaker must therefore be careful in his trade and selective in his choice of tools and materials. Yet, he also must work fast to produce the staggering number of blocks needed to fit out a heavy warship like *Vasa*.

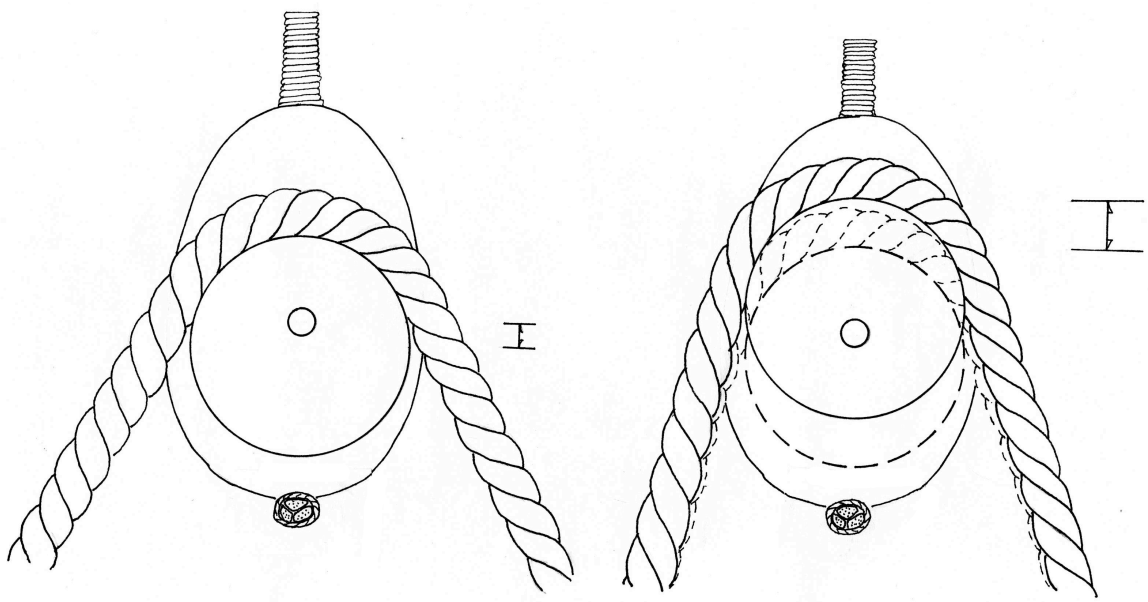


FIGURE 4.12. An eccentric sheave (left) or one that is not a perfect circle will turn with an uneven rate of uptake when in motion (right) causing violent jerking in the fall (Drawing by Nathaniel Howe, 2011).

Chapter 5. Rigging Systems of the Squaresail Running Rig

Manipulating just one of *Vasa*'s enormous square sails required a series of rigging systems. Tyes, halyards, lifts, braces, sheets, bowlines, and clews were all essential for managing the rig. Together, these systems required from 25 to 30 blocks of up to seven different types. Each of these systems was rigged to perform one of two tasks—to control the yard or to control the sailcloth. Figure 5.1 shows each of the key blocks in these systems and their typical arrangement.

Controlling the Yard: Tyes, Halyards, Lifts, & Braces

Controlling a large 17th century squaresail yard required a minimum of seven blocks including one halyard block, two upper lift blocks, two lower lift blocks, and two single blocks for the braces. These blocks had to be sturdy and well made. Even the smallest yards on *Vasa* weighed more than 100 pounds and the massive 10 meter-long mainsail yard loaded down with sailcloth and tackle weighed in at two or three tons—or even more if the sailcloth was wet.

Before the introduction of steel spars and yard trusses in the late 19th century, squaresail yards were typically supported by two rigging systems. The first system consisted of heavy lines called *tyes* (two for each course yard, one for each topsail and topgallant yard) that fastened around the middle of the yard to carry its weight. The second system consisted of pair of lines, called *lifts.* These were made of much lighter cordage and ran from the masthead diagonally down to the ends of the yard to keep it level (Figure 5.1).

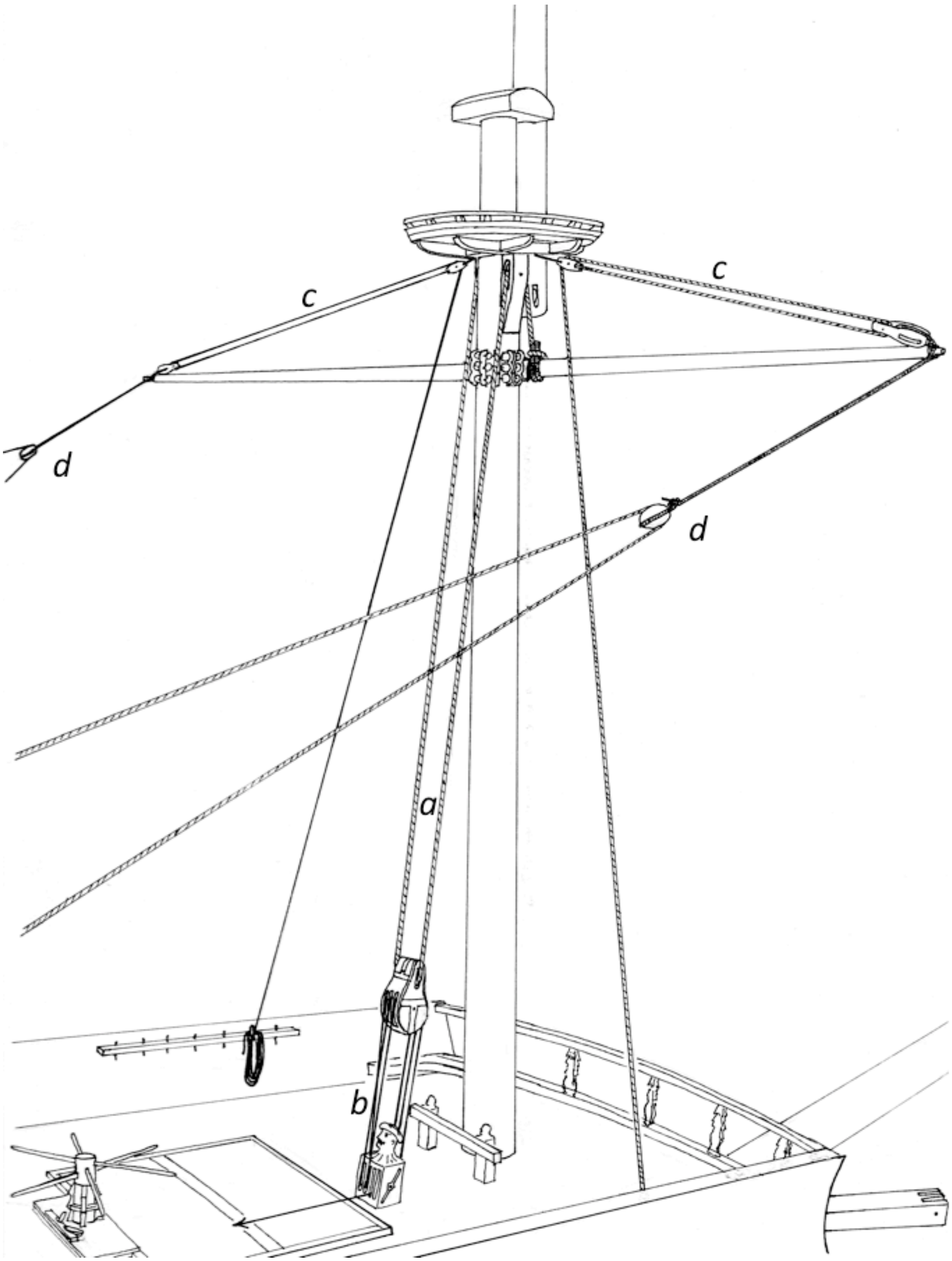


FIGURE 5.1. Diagram of the running rigging controlling the fore-course yard: (*a*) tyes, (*b*) halyard tackle, (*c*) lifts, and (*d*) braces (Drawing by Nathaniel Howe, 2011).

Aboard most ships of the period, the tyes ran up from the yard, through a set of blocks hung from the mast cap or top trestles, and then down to a large ram's head block just above the deck. Lighter cordage was rove between the ram's head block and a knighthead in the deck to form the halyard tackle. This was the standard *tye and halyard* system. Dutch rigging practices took a slightly different approach to the tye and halyard system by passing the tye over the curved top of the mast cap instead of using blocks. *Vasa*'s tye and halyard system was essentially a hybrid of these two methods, merging the block slung from the masthead into the mast itself. Just below the main- and foretops, *Vasa*'s masts were fitted with a pair of hounds each containing a bronze or iron sheave to carry the tye (visible in Figure 5.1).

Yet even with smooth-running sheaves at the masthead, hoisting one of *Vasa*'s heavy yards with all its sailcloth and cordage could not be done with brute force alone. The halyard tackle at the lower end was absolutely essential. *Vasa*'s specialized ram's head block (or *kardel block* in Swedish; meaning 'strand block' for the many strands of the tackle) carried three sheaves for the tackle fall which was rove to the three sheaves in the knighthead mounted on the deck and the standing end secured to the same, making a six-part tackle. Coupled with the capstan, this tackle could provide the mechanical advantage required to hoist the multi-ton spars. Topsail and topgallant halyards worked in essentially the same way, but were simplified as they carried smaller loads. They were typically rigged with just a single tye and the tackle at its lower end was seldom more than just a three-part tackle rigged between a fiddle block and a single block (Anderson 1927:133, 182-186).

Once aloft, the yard was kept level by the lifts. On larger yards, the lifts were usually doubled to gain a little mechanical advantage, running from the mast out to a block at the end of the yard (the *lower lift block*) and then back to the mast to pass through another block (the *upper lift block*) that took half the load and redirected the line down to the deck for handling (Figure 5.1). Smaller yards that did not require as much mechanical advantage were generally rigged without lower lift blocks at all; the lift simply being run from the end of the yard to an upper lift block and down to the deck.

In *Vasa*'s era, most European rigging traditions employed standard single blocks to rig the lifts on all yards except the main and fore course yards. These heavier yards were fitted with specialized lower lift blocks designed to sustain the increased load. These were also the only fixed yards that were not routinely raised or lowered and therefore required full-time dedicated lifts. The standing ends of the topsail lifts, by contrast, could be cast off from the mast and used as sheets for the topgallant whenever it was set (Figures 5.2. 5.3, and 5.4). The topgallant lifts were even less permanent as they were often taken down to the deck along with the whole topgallant yard and sail—and given the small size of the sail, lower lift blocks were often not used at all.

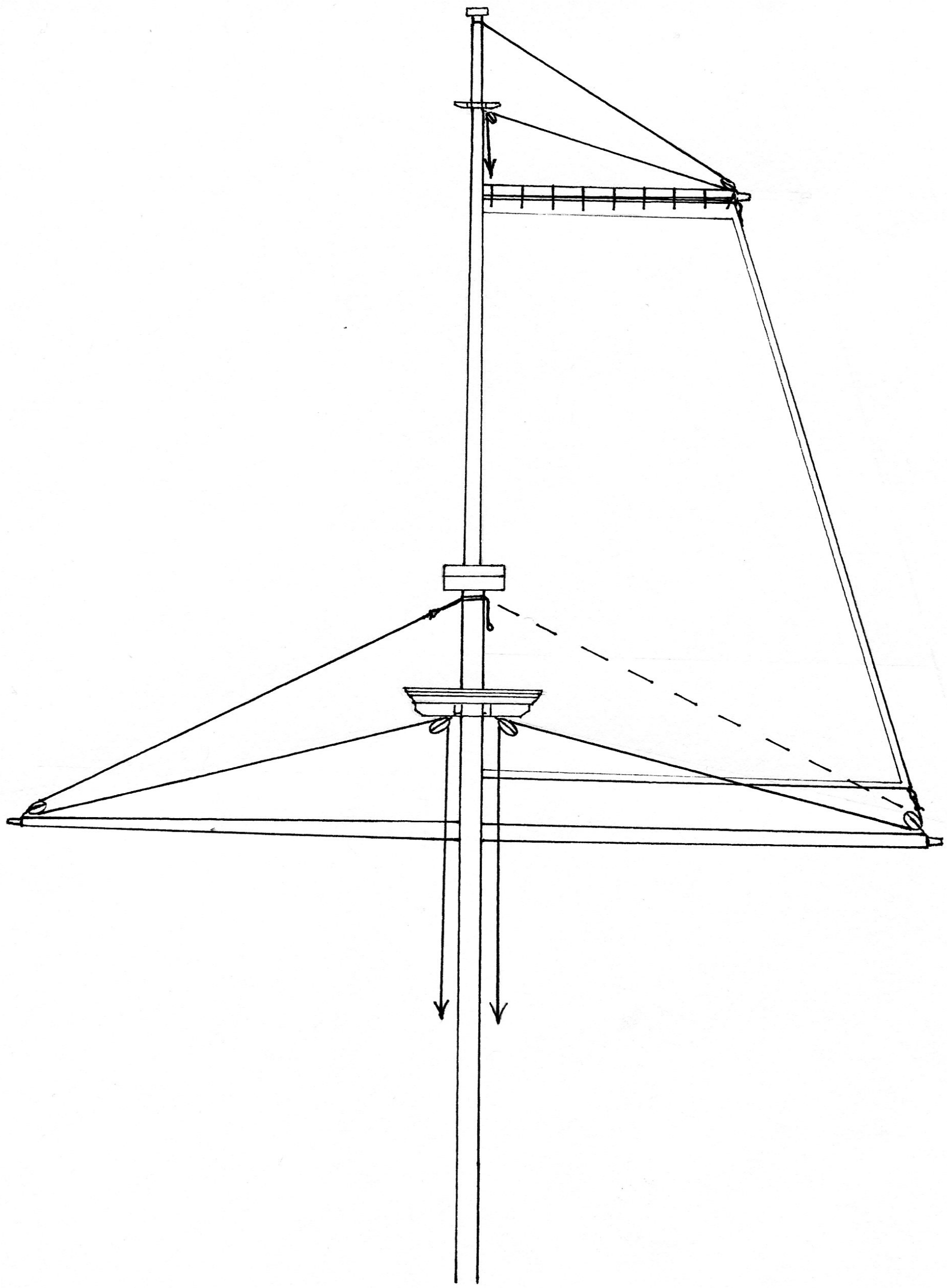


FIGURE 5.2. Diagram of topsail and topgallant lifts. Note the topsail yard lifts are rigged to the topmast head when the topgallant is struck. When it is set, the standing end of the topsail yard lifts are untoggled and fastened to the clew of the topgallant (Drawing by Howe, 2011).

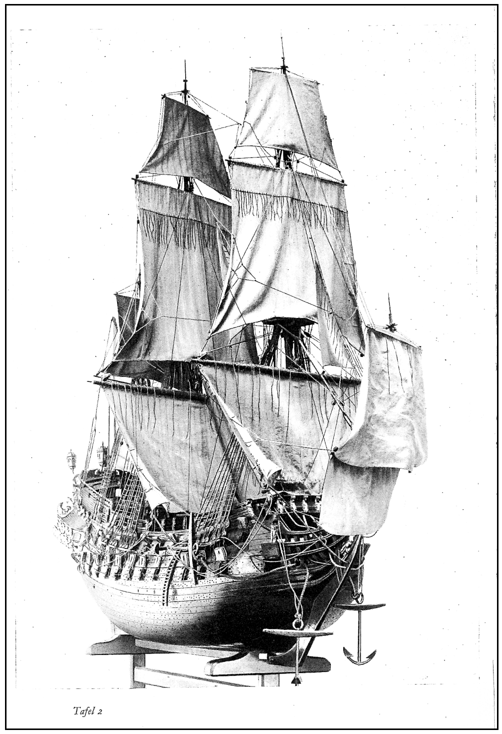


FIGURE 5.3. Der holländische Zweidecker von 1660/1670 housed in Monbijou Castle in Berlin until destroyed by Allied bombing in WWII (Winter 1967:*Tafel* 2).

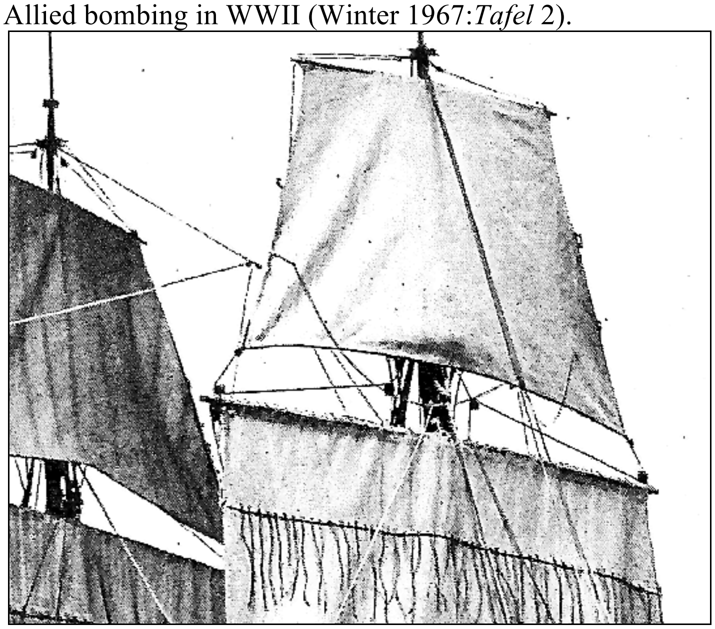


FIGURE 5.4. Close-up view of der holländische Zweidecker von 1660/1670 showing that the topsailyard lifts are run to the clews of the topgallant to serve as sheets (Winter 1967:*TafelI 2*).

The course yard lifts, however, were neither temporary nor multi-purpose lines. These were always rigged and strictly dedicated to keeping the yard at a desired angle.

This meant that the topsail sheet—which also requires a block at the end of the yard—had to have its own block. To prevent the lifts and sheets from chafing or tangling each other at the end of the yard, the two blocks were usually stropped together or combined into a specialized dual-function *topsail-sheet and lift block* that held the lines apart. French ships tended to use a fiddle block for this purpose while English rigging practices simply stropped two single blocks end-to-end, forming a sort of articulated fiddle block. The Dutch took it a step further, developing a highly specialized block specifically designed for service as a combined topsail-sheet and lift block (Marquardt 1986:74; Anderson 1927:147). This is the type rigged on *Vasa* (Figure 5.5).

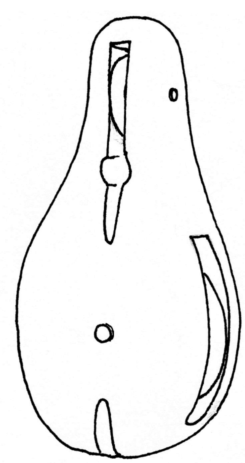


FIGURE 5.5. Dutch combined-topsail-sheet-and-lower-lift block (Drawing by Nathaniel Howe, 2011).

The Dutch combined topsail-sheet-and-lift blocks are easily recognizable by their pear-shaped form. The two sheaves are aligned end-to-end and set at 90 degrees to one another to keep their respective lines from fouling each other. The sheaves differ in size according to the load and cordage size they must carry. The larger of the two is for the topsail-sheet and is set in the broader part of the pear. The smaller sheave is for the lift and is set into the narrower neck-shaped portion of the block.

While specialized lower lift blocks for the course yards were standard, specialized upper lift blocks were a little less common. English and French vessels usually used a hefty single block or occasionally a fiddle block. Dutch-rigged ships were outfitted with specialized single blocks with flat elongated shells and an eyehole bored through each end perpendicular to the sheave (Marquardt 1986:74; Anderson 1927:146-147). When rigged, a short pendant from the masthead was secured through one eyehole and seized while the standing end of the fall was secured to the other eyehole. The fall then ran out to the lower lift block on the end of the yard and back to the upper lift block again, passing around the sheave and then continuing down to the deck for handling (Figure 5.1).

The third system required to control a squaresail yard aloft was the braces. Rigged from the end of the yards, the braces were used to pivot the yard around the mast horizontally, thereby altering the wind's angle of attack on the luff and maximizing the effort exerted upon the sail. Unlike the lifts, the brace systems become progressively more complicated higher in the rig, running aft to another mast or spar and then down through the rigging to the deck.

The course yard braces of small vessels were no more than a line run from each end of the yard aft to a cleat or pin on deck. Larger ships such as *Vasa* required mechanical advantage and used a single block on a long pendant from the yardarm to double the brace and halve the force required to move the yard (Figure 5.1). The ship's topsail and topgallant yard lifts were also doubled, but employed additional single blocks to redirect the lines around fouling hazards on their way down through the rigging to the deck.

All yard braces on *Vasa* were rigged to run aft from the yard. By the 18th century, many ships ran the mizzen braces forward to the mainmast as there were no places aft of the mizzen to affix a line. *Vasa*'s high stern castle and the high peak of the mizzen lateen yard, however, permitted the mizzen braces to be secured to an elevated position aft of the mizzenmast (Figure i.1).

Controlling the Sailcloth: Sheets, Buntlines, Clews, Bowlines, and Martnets

Controlling the sailcloth of just one sail on a large square-rigged ship requires anywhere from 15 to 25 blocks. The steel-masted Cape Horners of the 19th and early 20th centuries sometimes had as many as 35 per sail. For a ship of *Vasa*'s size and rig, 18 to 22 blocks per squaresail was common. The rigging systems for handling the canvas itself can be described in two groups; those used to set the sail and those used to strike it. These systems are essentially the same for all of *Vasa*'s sails, but there are a few differences between the topsails and topgallants and the heavier courses.

The first rigging system for handling the sailcloth that required blocks was the sheets. The sheets drew down on the clews of the sail and prevented it from billowing out and spilling the wind like a bed sheet on a clothesline. The topsail and topgallant sheets ran up from the deck to a pair of quarter blocks hung from the middle of the yard below the sail they controlled. The quarter blocks redirected the sheets out toward the end of the yard where they passed through sheet blocks that redirected them up to the lower corners of the sail (Figure 5.6). For these sails, both the sheet block and the quarter blocks were used to redirect the lines out to the ends of the yards to obtain an effective angle of purchase.

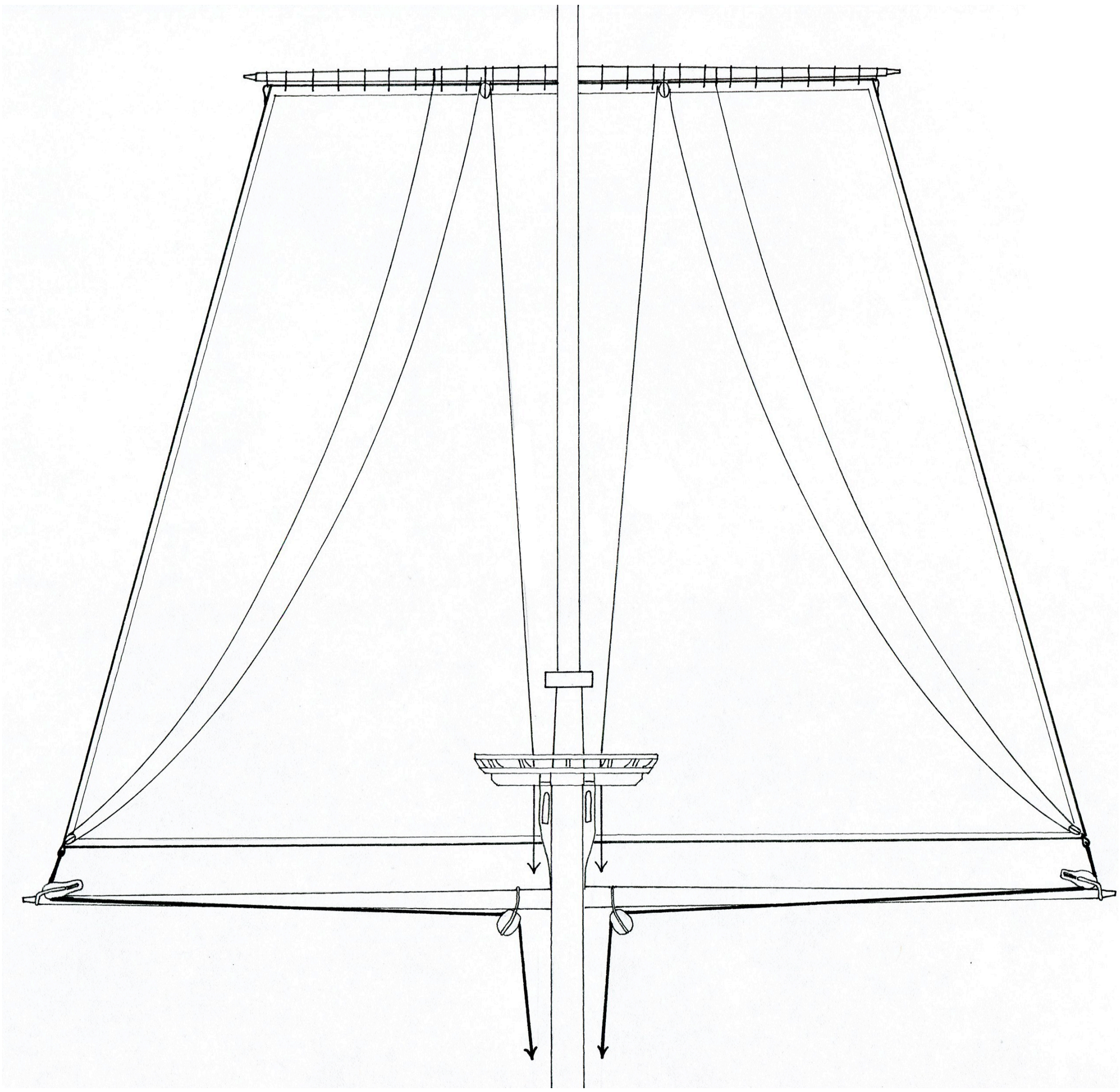


FIGURE 5.6. Routing of the topsail sheets and topsail clews (Drawing by Nathaniel Howe, 2011).

The main-course and fore-course sheets, however, were rigged quite differently (Figure 5.7). Without a yard beneath these sails to anchor a sheet block, the sheets were run directly to the hull, passing through fairleads in the bulwarks near the belaying points. Although there was no need to redirect the sheets on their way from the sail to the fairlead, sheet blocks were still rigged on these free-footed sails. Unlike the topsail and topgallant sheet blocks that were secured to the yards, the mainsail and foresail sheet blocks were attached to the sail itself. In this position, instead of redirecting the pulling forces, they served to double the sheet back to the hull, providing a 2:1 mechanical advantage for controlling the large expanse of billowing canvas.

If the ship was to be sailing to windward, two more running rigging systems were needed to control the sailcloth: tacks on the main and fore courses and bowlines on all of the square sails. The tacks were lines affixed to the clew and run forward to fairleads and kevels or belaying points on the main deck or bowsprit. Blocks were not typically used in rigging the tacks in the 17th century (Hoving 2000:80).

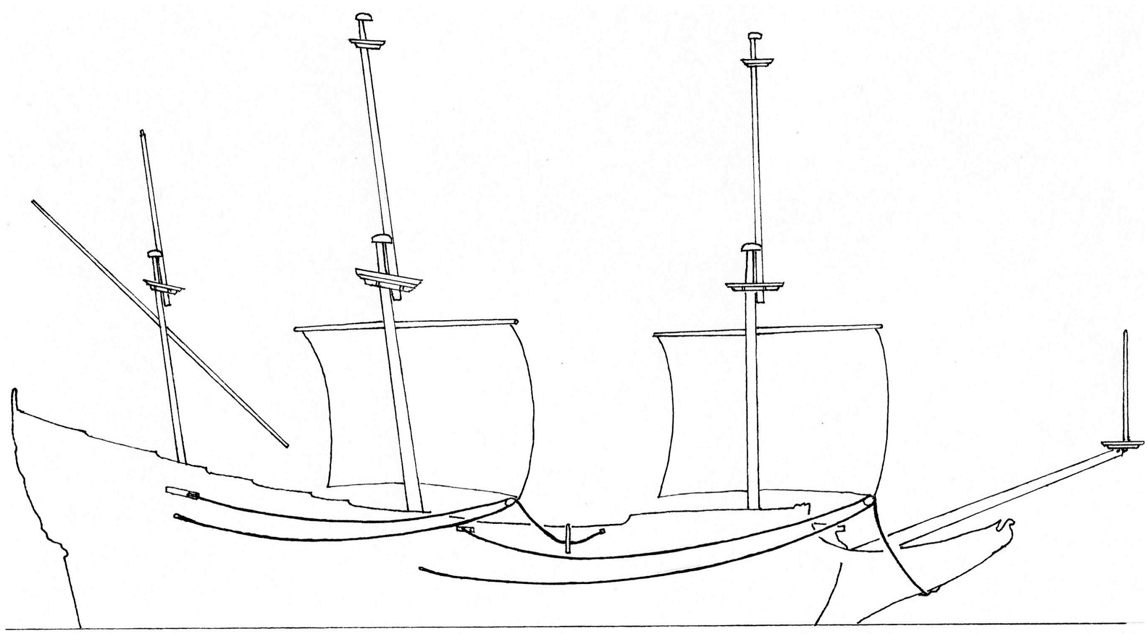


FIGURE 5.7. Routing of the main and fore course sheets and tacks. These two rigging systems control the clews of the courses. The standing ends of the sheets are secured to ring bolts on the hull, run forward to the clew of the sail, pass through the sheet block, then run aft to a sheaved fairlead in the bulwarks that leads the sheet to the belaying point. The standing end of the tacks is affixed to the clews of the sails and run forward to fairleads on the side of the hull (main course) or under the beak head (fore course). (Drawing by Nathaniel Howe, 2011).

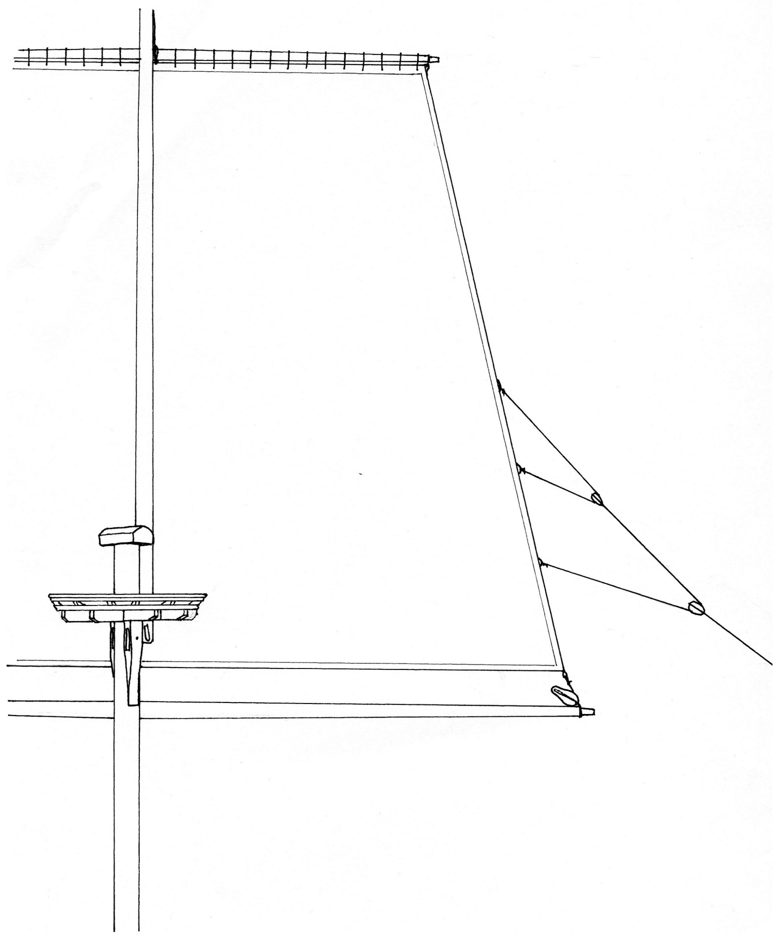


FIGURE 5.8. Bowline configuration on the foretopsail (Drawing by Nathaniel Howe, 2011).

The bowlines were lightweight lines tied off to the sides of a squaresail and used to prevent the luff, or windward edge, of the sail from curling backward in the wind—a situation that usually resulted in back-winding the sail and stalling the ship while the crew scrambled to reset the sails (Figure 5.8). When in use, the bowlines on the windward side were drawn forward to hold the luff clear and keep wind in the sail. The leeward bowlines were slacked off until the ship changed tack. In order to avoid undue distortion of the sail's shape, the bowlines were rigged in bridles that distributed the tension along the luff. In *Vasa*'s era, these bridles were usually set up with dead blocks, thimbles, or simple eye-splices (Hoving 2000:82). The bowline system was completed by a series of single blocks redirecting the line down through the rig to its belaying pin on the deck level. Seventeenth century Dutch-rigged ships like *Vasa* also included a snatch block at the base of the foremast as part of the mainsail bowline system (Anderson 1927:166). *Vasa*'s bowline systems probably required three to five blocks each.

Keeping one of *Vasa's* squaresails set therefore required only eight to 12 blocks. The topsails required the most as the sheets and bowlines had to be redirected down through the rig whereas the systems rigged to the courses were already close to their belaying points on the deck level. To take in sail, however, required three more running rigging systems and another six to 14 blocks, depending on the sail. The three systems included the clew-garnet tackle to haul up the clews, the buntlines to draw up the belly of the sail (courses only), and the martnets (courses only) or leech lines (topsails only) to draw in the sides of the sail.

The clew-garnet tackle was a simple two-part tackle run between a single block secured to the clew and another single block hung from the yard (Figure 5.9). The clew-garnet counteracted the sheet and tack, hauling the clew back up to the yard for furling. It could also be drawn taut when the sail was set to serve as a rolling tackle (Fred Hocker 2011, pers. comm.). The rest of the sail was gathered up by hand or, on the larger courses, by buntlines running from the foot, up the forward face of the sail and through pairs of small single blocks hung on the yard (Figure 5.9). The lines then ran to another block on a stay and down to the deck. The leeches (leech and luff, when the wind is blowing from the side) of the main and fore courses were drawn up by the martnets—bridles of thin lines tied to cringles on each of the sail's leeches that ran up both the fore and aft faces of the sail, gathered in deadeyes, and were then joined together by a shared fall running through a shoe block suspended above the yard (Figure 5.10). This, in turn, was hauled upward by a two-part fall running from the deck to a block at the masthead, down to the shoe block, and then doubled back to the masthead. The topsails were not rigged with martnets, but were handled by leech lines instead. These were tied off to cringles on the leeches of the sail and run to single blocks beneath the tops and then directed down to the deck (Figrure 5.11).

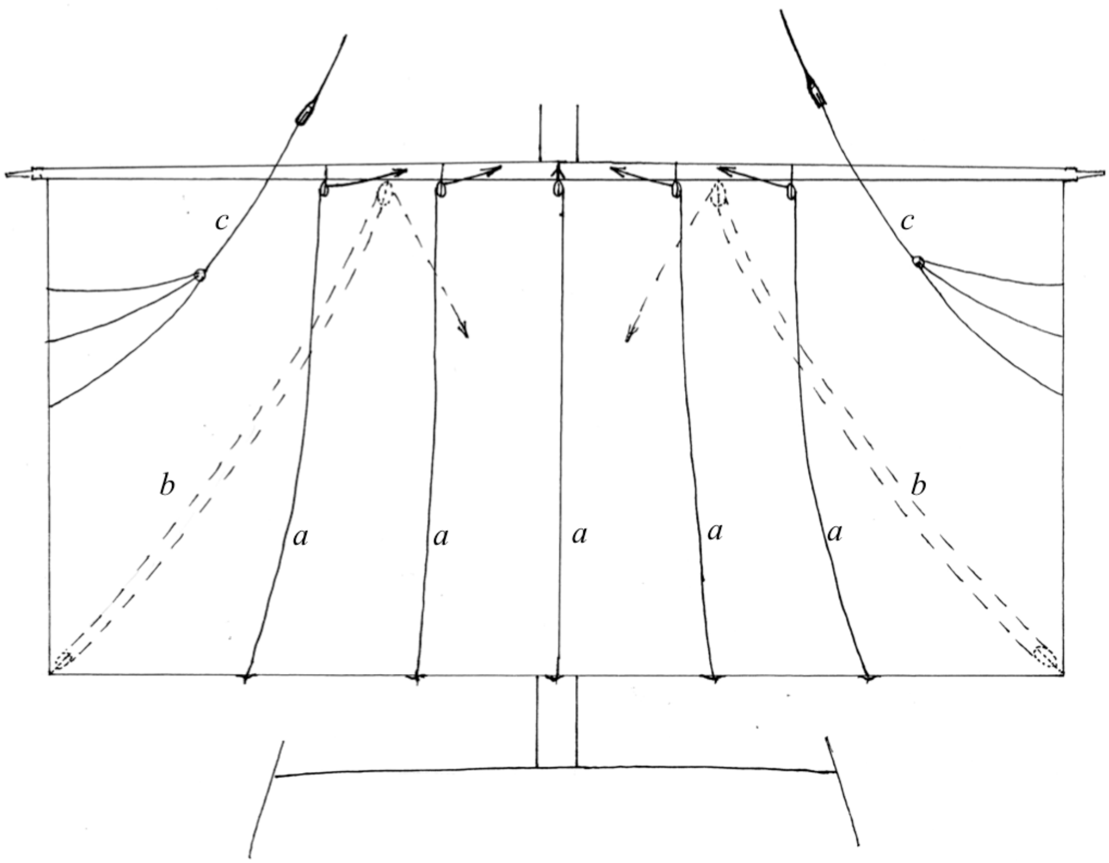


FIGURE 5.9. The three principal running rigging systems for taking in the main and fore courses: (*a*) buntlines, (*b*) clew-garnets, (*c*) martnets (Drawing by Nathaniel Howe, 2011).

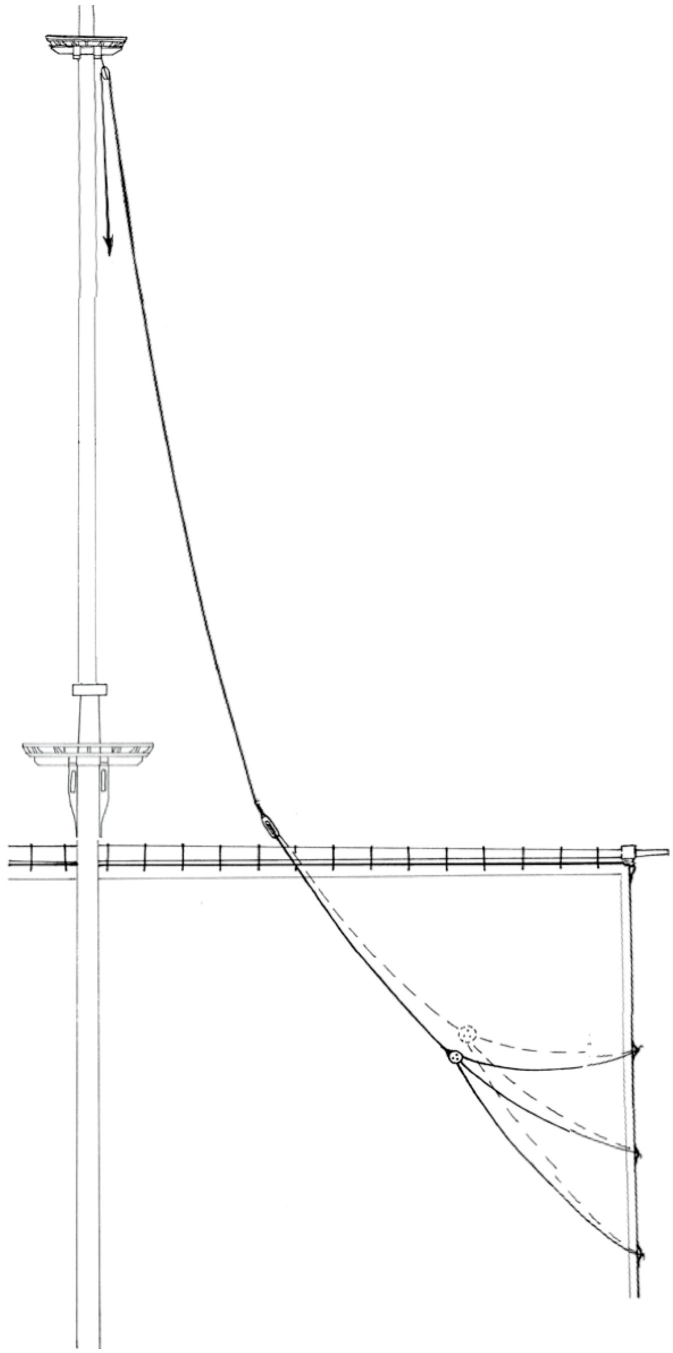


FIGURE 5.10. Martnet system (Drawing by Nathaniel Howe, 2011).

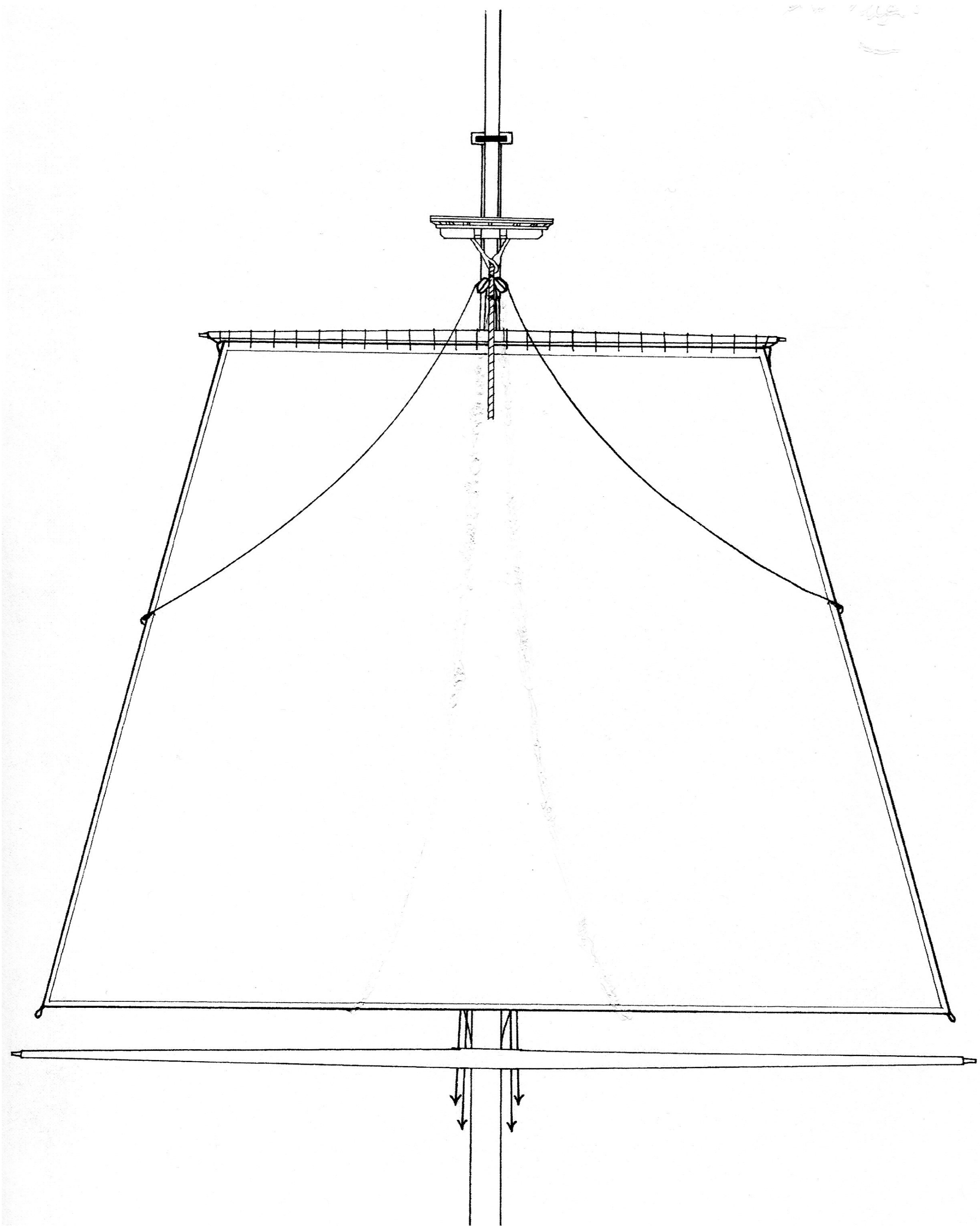


FIGURE 5.11. Leech lines used to draw in the leeches of the topsails and topgallants (Drawing by Nathaniel Howe, 2011).

The Squaresail Under Control:

Combining all the blocks needed to control the yard and the sailcloth, a squaresail on a Dutch-rigged vessel of *Vasa*'s size could required anywhere from 20 to 45 blocks. *Vasa*'s unusually large main-course needed somewhere between 37 and 43 blocks (depending on the bowline configuration) including six fixed blocks in the hounds and bulwarks. Just above it, the main topsail required 27 blocks to trim the sail and guide the lines down to the deck. Even the little topgallant was fitted out with half a chandler's shop, requiring 23 blocks to keep it under control. Adding top ropes and mast tackles, the mainmast alone was saddled with 75 blocks of seven types and numerous sizes. No other article of shipboard hardware was used in such abundance or so essential to the operation of the squaresail rig.

Chapter 6. *Vasa*'s Blocks

Introduction

A total of eleven distinct block types were recovered from the harbor bottom with *Vasa*. They range in size from a tiny 83mm dead block (Fnr 04729) to a man-crushing, iron-sheaved, ram's head block more than a meter in length (Fnr 09843). The variability in both the size and form of these blocks provides crucial insight into block technology and production methods in early 17th century Sweden as well as important clues for reconstructing *Vasa*'s rig. Within each major block type there are several sub-types defined by style, wood species, shell size, or cordage capacity.

Each block type and sub-type found in association with *Vasa* is presented below, organized in the same hierarchy of complexity employed in the block type nomenclature. Although this section categorizes blocks by form and strives to examine them independent of purpose, some block types are readily identifiable as common 17th century European block types (e.g. fiddle blocks, snatch blocks, or ram's head blocks) and thus function-based common names are used in these cases. More atypical block types, however, are described entirely by form.

For sorting the sub-types into size groups, overall shell size is important and is frequently used to describe various blocks in this text, but it is not the most crucial dimension. In part, this is because examination of the blocks reveals notable variability in shell length among blocks that are otherwise identical. Shrinkage of the wood during the 50 years since the ship was raised has introduced further variability in shell size as demonstrated by comparing axle length to shell thickness—dimensions that should match very closely but typically differ by up to 10mm in *Vasa*'s conserved blocks. Yet, beyond these inconsistencies, shell size—considered from a functional perspective—simply has little bearing on the performance of the block beyond basic strength. The more critical dimensions are those pertaining to the cordage passing through or around the block. Therefore, the width of the sheave, swallow, and strop score are used as the determinants of a block's size grouping (Figure 6.1).

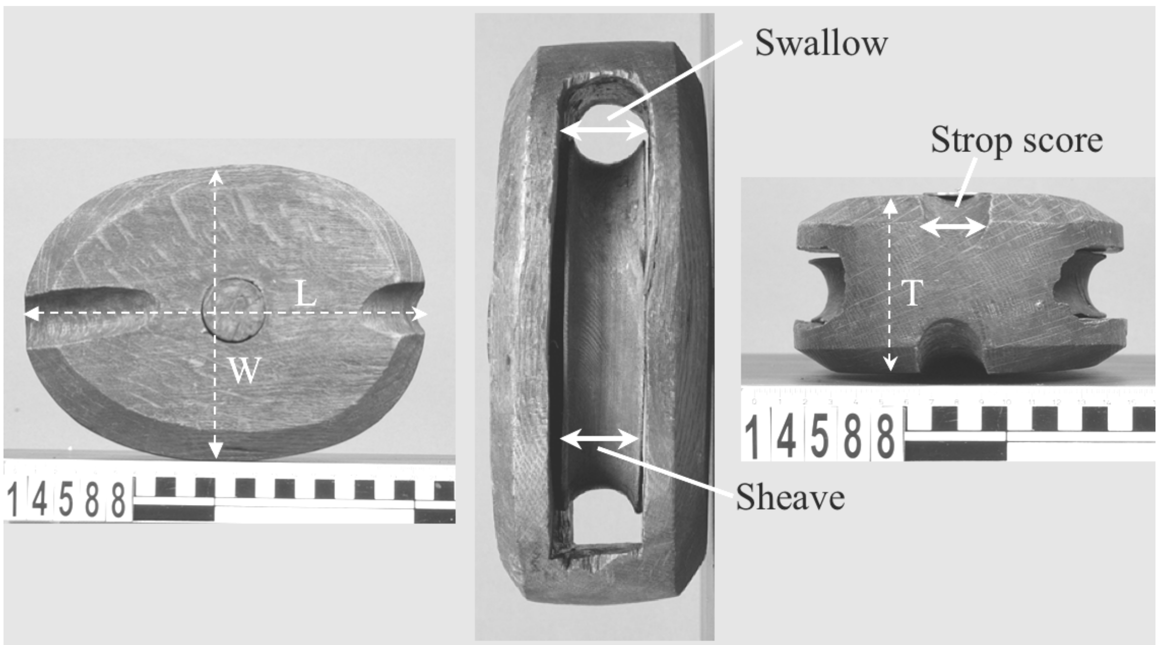


FIGURE 6.1. The key dimensions of a block. Measurements pertaining to the cordage are more critical than the overall length, width, and thickness of the shell for determining the proper size grouping for any particular block (Illustration by Nathaniel Howe, 2011).

Ultimately, it is these dimensions that dictate whether or not the block will function reliably. If the sheave is too thick it will jam and resist the line passing over it, if the swallow is cut too narrow the line will jam in the block, and if the strop score is too narrow then the block will pop out of the strop and foul the line. Any of these situations can have serious consequences for the entire ship and crew. A jammed block can paralyze the rig and send the ship out of control—a perilous situation in battle or on a lee shore.

To prevent lines from jamming in the blocks, a certain level of standardization was essential. Cordage for the navy was ordered in just a handful of specified diameters and *Vasa*'s hand-made rigging hardware was produced using patterns, making them remarkably consistent in size and form—a blessing when conducting a survey of the 412-piece collection. These measures ensured compatibility among the hundreds of blocks and several thousand meters of cordage in *Vasa*'s rig. Consequently, an examination of the form of a block must include the key dimensions of the sheave, swallow, and strop score.

In examining the form of these blocks, plenty of physical evidence of the production process was also observed. Chisel marks, lathe grooves, and auger channels are common features. Although some of these are noted in this discussion of form, the discussion of block production is worthy of its own section. Accordingly, that discussion is postponed until the latter chapters of this thesis.

Non-sheaved blocks

The simplest block form associated with *Vasa* is the non-sheaved block (Figure 6-2). Although very similar in size and shape to many of the other blocks recovered, these are far less complex and consist of only a shell with no sheave, axle, or sheave mortise. Instead, they have a smooth curving passageway bored out of the shell to carry the fall as it flexes through the block. This hole is flared at both ends to create swallows and the outside of the shell is carefully shaped and finished with strop scores set into the cheeks.

This form was known as a dead block for its lack of moving parts. Although some may consider these blocks to be more akin to other non-sheaved items of rigging hardware such as thimbles, fairleads, or deadeyes, a non-sheaved block actually serves the same function as a sheaved block, carrying lines of the running rigging around sharp bends.

Eighteen of these non-sheaved blocks were recovered with *Vasa*. They appear in three general forms—oval, oval with flat ends, and elliptical—and range significantly in size (Figure 6.2). The largest non-sheaved block is 259mm (Fnr 18909) in length while the smallest measures only 83mm (Fnr 04729)—the smallest block of any type found in association with *Vasa* (Table 6.1).

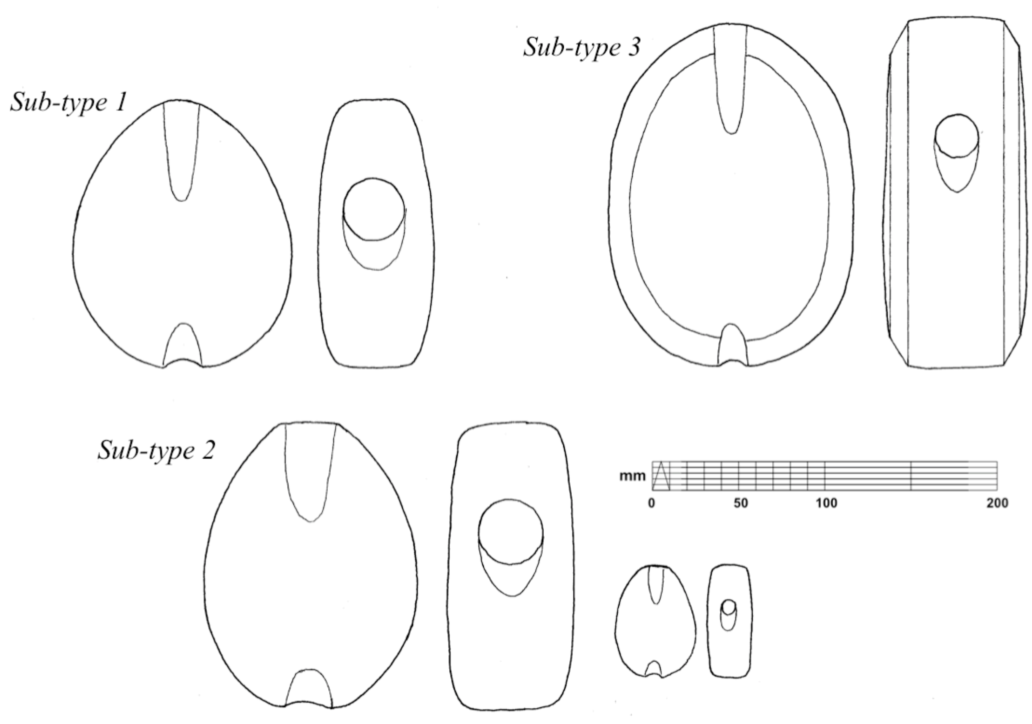


FIGURE 6.2. *Vasa*'s dead block forms. Each of these three sub-types range significantly in size, as illustrated for *sub-type 2*. Shown 20490, 18869, 00405, and 18870 (Drawing by Nathaniel Howe, 2011).

Vasa's Deadblocks

Find Number	Sub-type	Swallow size (mm)	Length (mm)	Width (mm)	Thick-ness (mm)	Wood species	Strop size (mm)
18902	1	40	250	175	76	ash	28
20490	1	47	203	165	85	ash	32
00405	2	16	85	63	41	ash	13
04729	2	18	83	46	40	ash	7
23257	2	19	85	47	36	ash	unknown
11658	2	34	167	131	72	ash	22
07759	2	36	166	134	66	ash	24
19713	2	38	175	126	69	ash	25
19741	2	38	182	142	92	ash	28
18983	2	40	241	167	87	ash	27
18903	2	41	215	176	95	ash	35
18880	2	42	204	165	91	ash	28
18909	2	49	259	186	109	oak	45
18984	2	51	202	144	86	ash	unknown
18869	2	51	217	159	96	ash	38
05616	2	57	149	110	60	ash	unknown
18870	3	33	168	126	68	oak	23
15760	3	35	162	121	72	oak	27

TABLE 6.1.
Table of diagnostic information for *Vasa*'s dead blocks (Table by author, 2011).

Style 1. Oval. Only two examples of the oval-shelled style survive. They are carved from hefty chunks of ash wood (*Fraxinus*) with smooth rounded edges and a sturdy length to width ratio of approximately 4:3. They are both fairly large among the non-sheaved blocks recovered, one measuring in at 203mm (Fnr 20490) and the other at 250mm (Fnr 18902). Although these two blocks are significantly different in overall size, they are made to handle the same diameter cordage. The two oval-shelled examples vary only slightly in swallow diameter (40mm versus 47mm) and oddly enough, it is the larger block that has the narrower swallow. Erosion of the wood surfaces may be a factor, opening up the swallow of the smaller block, but it is more likely that shell length simply was not particularly standardized.

Style 2. Oval with flat ends. The second style of non-sheaved block—oval with flat ends—is by far the most prevalent. Thirteen examples of this style exist in the collection in seven distinct shell sizes with swallows cut for four sizes of cordage. All are carved from ash with smooth, rounded edges. The smallest in this style are the tiny 85mm blocks (Fnrs 04729, 23257, & 00405). These carried light-duty cordage no larger than 15mm in diameter. Only three examples survived and two of them are badly eroded, but the third (Fnr 00405) is in remarkably good condition with only some slight chipping (shown in Figure 6-2).

The second group of flat-ended oval blocks is intended for somewhat heavier line with swallows ranging from 34mm to 36mm. This group includes two 165mm-long blocks (Fnrs 07759 & 11658) and a third example (Fnr 05616) that is severely eroded but most likely once matched the other two in essential dimensions. Next is a pair of blocks with 38mm diameter swallows, one block being 175mm long and the other 185mm. These are potentially part of the previous group given the narrow variance in swallow diameter; however, the 20mm variability in the length of the block shells may be an important difference. Likewise, another pair of these blocks with swallows for 40mm cordage have shells ranging from 204mm to 215mm while the final pair made with 51mm swallows completely brackets those shell sizes, ranging from 202mm to 217mm. Looking at just the blocks with 40mm and 50mm cordage capacities, there seems to be no direct relationship between cordage size and shell length.

Style 3. Elliptical. The third style of non-sheaved blocks—those with elliptical shells—stand out from the rest rather significantly. Only three examples survive, but unlike the other styles that are made with smoothly rounded edges, these blocks are carved with crisp, chamfered edges. Equally striking is the fact that all of the elliptical-shelled blocks are made of quarter-sawn oak, not slab-cut ash. Two of these elliptical blocks have swallows cut for roughly 30mm cordage (Fnrs 18870 & 15760) and the third for line approximately 45mm in diameter (Fnr 18909). The latter has the largest shell of any of the non-sheaved blocks found in association with *Vasa*, measuring in at 259mm.

Sheaves

Although the sheaves are not treated separately in the nomenclature system, they are worthy of independent examination. Three distinct sheave types appear in the *Vasa* collection (Figure 6.3). These include both sheaves that were still fitted in block shells as well as more than 60 others that had fallen out of broken blocks. The vast majority of the sheaves are made of ash. They are slab-cut very close to the center of the tree or limb such that the pith runs across one face of the sheave. The tight curvature of the growth rings is clearly visible on the circumference of the sheave where the end-grain is exposed. (Figure 6.4). Most of these sheaves have an average diameter-to-thickness ratio of approximately 4.5:1. Tool marks appear on the flat faces of the sheaves, usually in the form of broad chisel marks (i.e., Fnrs 09502, 08194, 08522, & 16718) or a series of several concentric grooves cut while the sheave spun on a lathe, each 2-3mm wide and set near the outer edge of the flat faces (i.e., Fnrs 18982, 12523, & 21454) (Figure 6.5).

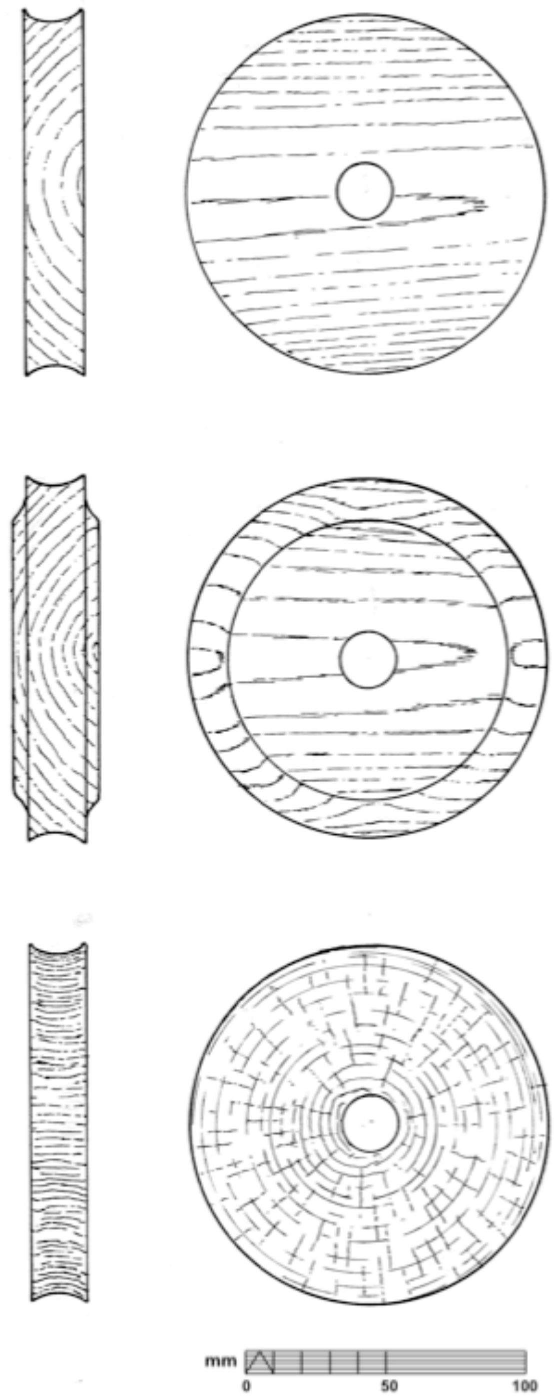


FIGURE 6.3. The three different types of sheaves recovered from *Vasa* shown in their average sizes. The upper two sheaves are ash. The lower sheave shown is made of *lignum vitae* (Drawn by Nathaniel Howe, 2011).

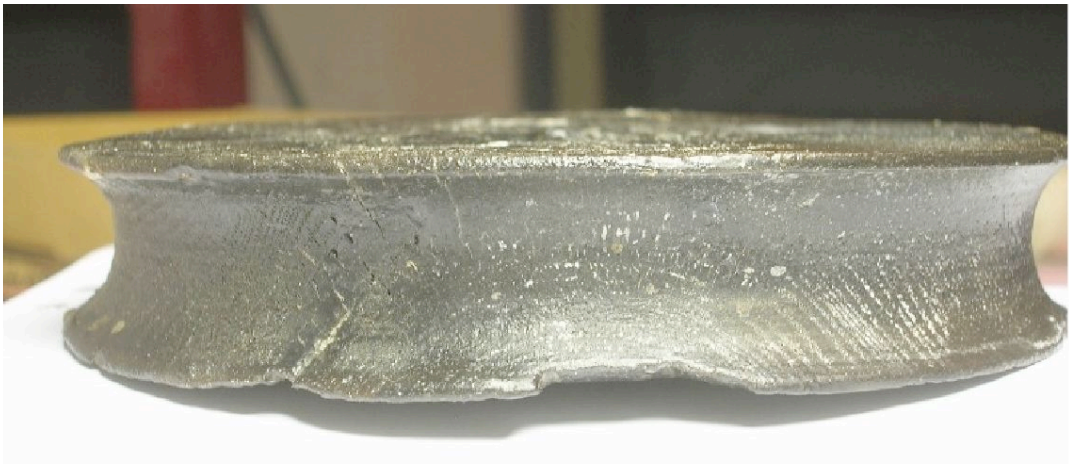


FIGURE 6.4. End-grain of an ash sheave. Note the curvature of the grain, indicating how closely this wood was harvested from the center of the trunk or limb of the tree (Photo by Nathaniel Howe, 2007).

FIGURE 6.5. Circular lathe grooves in the sheave face (Photo by Nathaniel Howe, 2007).

The second type of sheave, also made of slab-cut ash, is carved with heavy cheeks on either face, each 5mm thick. There are just two examples of these (Fnrs 08387 &

08388), respectively measuring 156mm and 170mm in diameter. The cheeks are a little smaller in diameter, ending roughly 10mm shy of the edge of the sheave (Figure 6.6).

FIGURE 6.6. Cheeked sheave (Photo courtesy of Vasamuseet).

FIGURE 6.7. A fragment of a *lignum vitae* sheave that broke along the grain. The axle hole is at the top (Photo courtesy of the Vasa Museum).

The third group consisting of 12 sheaves is significantly different and, based on material and find location, were probably deposited on the site after *Vasa* sank. Chapter 8 will explore this matter more in depth. These 12 sheaves are made of *lignum vitae*, or guiacum wood, imported from the New World. Instead of being slab-cut like the ash sheaves, these are cut as cross-sections of the trunk or limb. The resulting short grain running between the sheave's faces is most likely the cause of so many of these sheaves being broken despite *lignum vitae*'s resistance to splitting along the grain (Figure 6.7). Tool marks were not found on any of these sheaves and only one was still fitted in a block when recovered (Fnr 20746). Two of these sheaves—Find Number 08697 and an unnumbered sheave provisionally tagged NN19—however, have an inset chiseled out near the axle for bow-tie-shaped iron bearings to be fitted (Figure 6.8).

FIGURE 6.8. Bow-tie shaped iron bearing mortise in one of the *lignum vitae* sheaves found in association with *Vasa* (Photo courtesy of the Vasa Museum).

Single Sheaved Blocks

Single sheaved blocks are the most common type found aboard ships. As the least specialized block variant, they can be employed in the widest variety of capacities. Accordingly, single sheaved blocks are by far the most abundant block form associated with *Vasa*. Out of the total 630 rigging and gun tackle blocks that would have been rigged on *Vasa*, more than 450 were single blocks. A total of 273 single blocks (66% of all blocks found) were recovered from the wreck site along with fragments of up to 100 others. They range in size from only 110mm in length to over 540mm and can be grouped into 12 distinct sub-types or styles.

The bulk of the single blocks are consistent with classic 17th century block designs. They have flat, one-piece wooden shells that are either elliptical or slightly oval in profile, wooden axle pins, wooden sheaves, and no metal bearings or bushings of any kind. The sheave mortises are cut flat across the empty end and rounded out in the head to accept the fall. Unlike the blocks recovered from other large European wrecks (e.g. *Mary Rose, General Carlton,* or *Amsterdam*), however, *Vasa*'s rigging hardware is almost exclusively made of ash or oak with no use of elm at all. In fact, ash is the predominant species in the collection, amounting to just over 71% of *Vasa*'s single blocks.

Sub-type 1. Elliptical Blocks with Chamfered Edges. Eighty percent of *Vasa*'s single blocks are of the same type and style (Figure 6.9). These 219 blocks all have elliptical shells with crisply chamfered edges and swallows ranging from 19mm to 50mm in width to handle at least five standardized cordage sizes (Table 6.2). Many of these blocks have a becket recess chiseled out of the foot and their shells range in length from just 142mm on up to some hefty 480mm blocks. The vast majority, however, average approximately 230mm overall. The sheaves set into these blocks are ash, tending to be 27-29mm thick and approximately 140mm in diameter.

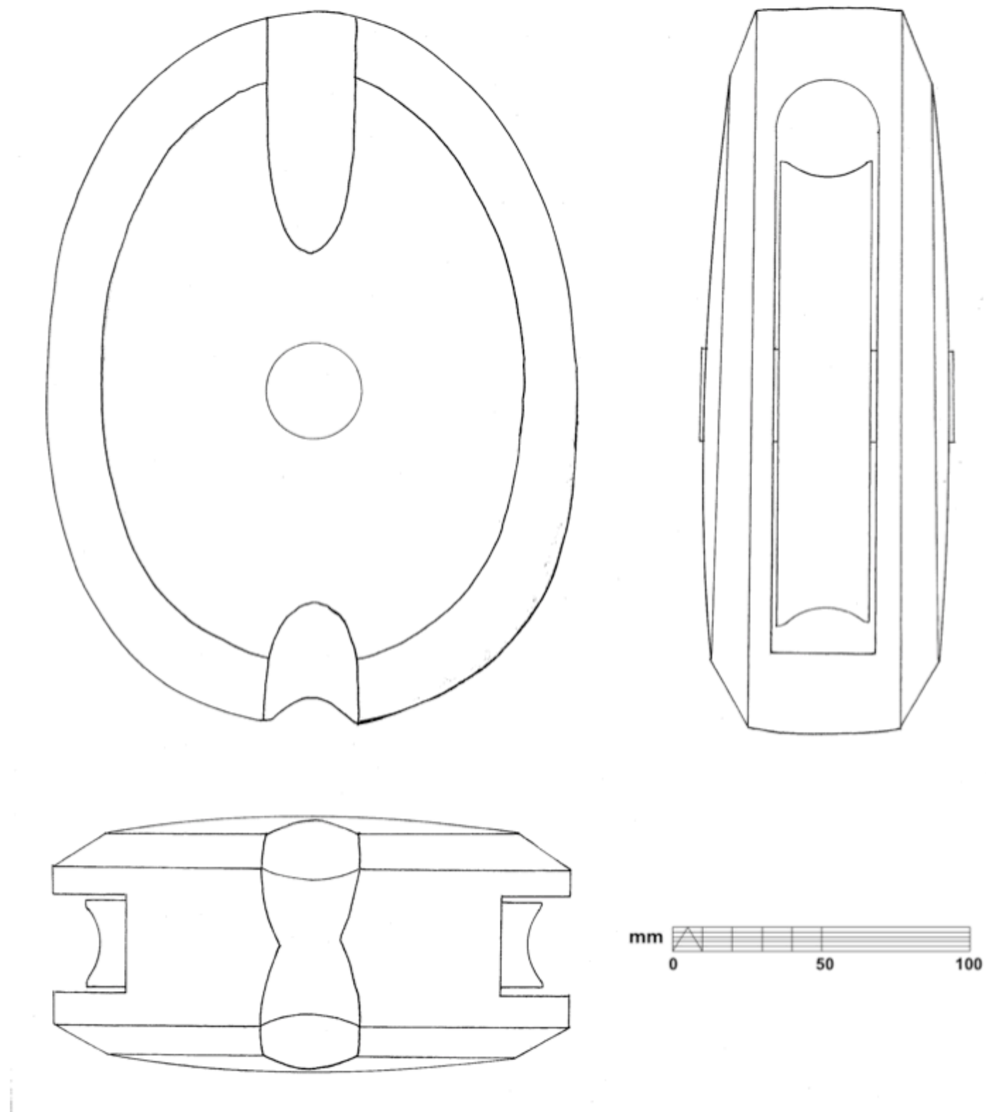


FIGURE 6.9. A *sub-type 1* single block with an elliptical shell and chamfered edges. (Drawing by Nathaniel Howe, 2011).

Sub-Type 1 Single Blocks

ID	Shell								Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Strop type	Dia. (mm)	Thick-ness (mm)	Wood Species	Length (mm)	Dia. (mm)
08788	23	oak	151	100	68	11	11	rope	81	18	ash	71	21
12427	24	ash	174	115	61	16	23	rope	113	21	ash	62	23
16120	25	ash	142	90	53	11	17	rope	80	20	ash	58	20
07143	25	ash	145	90	50	eroded	16	rope	89	22	ash	55	21
15711	26	oak	200	139	70	17	21	rope	127	24	ash	unknown	24
15256	27	oak	180	123	65	16	20	rope	120	23	ash	66	22
18879	27	oak	201	129	76	16	21	rope	124	24	ash	80	25
12425	28	ash	148	95	70	eroded	unknown	rope	80	19	ash	72	20
NN12	28	oak	158	110	61	10	20	rope	103	23	ash	64	22
23282	28	ash	168	107	62	11	19	rope	95	21	ash	65	25
19919	28	oak	181	128	73	15	25	rope	120	25	ash	72	25
19994	28	oak	188	129	67	17	24	rope	missing	missing	missing	missing	missing
16490	28	ash	189	126	67	16	22	rope	missing	missing	missing	missing	missing
14898	28	oak	193	138	70	14	24	rope	125	23	ash	70	26
18911	28	ash	195	127	71	16	23	rope	119	23	ash	77	27
19716	28	oak	225	153	82	20	30	rope	136	25	ash	85	29
15598	29	oak	161	114	61	14	unknown	rope	103	22	ash	62	22
12426	29	oak	180	120	59	eroded	unknown	rope	110	25	ash	70	25
10522	29	ash	196	127	67	16	23	rope	122	26	ash	70	25
15375	29	ash	199	115	68	13	26	rope	112	24	ash	71	25
07756	29	oak	210	121	75	18	24	rope	missing	missing	missing	missing	missing
13888	30	oak	185	131	71	eroded	22	rope	155	30	ash	75	26
19995	30	oak	189	128	77	16	25	rope	117	25	ash	79	24
19440	30	oak	192	137	63	19	21	rope	121	28	ash	68	26
19429	30	oak	193	139	70	17	25	rope	125	26	ash	75	27
19907	30	oak	193	117	77	17	22	rope	115	28	ash	78	25
18778	30	oak	194	122	73	17	22	rope	124	27	ash	75	25
02073	30	ash	195	125	66	14	21	rope	114	26	ash	70	25
16388	30	oak	198	120	77	17	25	rope	125	24	ash	78	24
21760	30	ash	198	129	66	13	21	rope	119	24	ash	71	27
19722	30	ash	202	132	69	13	25	rope	127	28	ash	73	26
24236	30	ash	203	146	74	16	25	rope	140	26	ash	73	26
14099	30	oak	209	145	71	eroded	26	rope	139	25	ash	77	27
15759	30	oak	209	146	82	19	23	rope	133	27	ash	87	26
18986	30	oak	216	147	82	16	23	rope	147	27	ash	81	27
17996	30	oak	217	142	83	16	20	rope	140	26	ash	85	28
19999	30	ash	218	138	87	21	24	rope	142	28	ash	89	26
08181	30	oak	220	149	79	19	31	rope	138	24	ash	80	26
19901	30	oak	221	146	80	20	28	rope	135	24	ash	82	27
NN01	30	oak	222	142	76	eroded	21	rope	141	26	ash	85	27
10165	30	ash	224	140	81	eroded	23	rope	139	29	ash	82	27
14586	30	ash	227	155	78	19	31	rope	144	26	ash	85	28
18878	31	oak	186	133	69	eroded	22	rope	124	28	ash	72	25
19742	31	oak	192	141	70	16	23	rope	130	27	ash	70	26
19746	31	oak	196	137	69	16	22	rope	130	27	ash	74	27

TABLE 6.2. List of the *sub-type 1* single blocks recovered with *Vasa* organized by swallow size. Iron stropped examples are grouped near the end, just before the blocks of unknown swallow size (data gathered from *Vasa* block collection; table by Howe, 2011).

Sub-Type 1 Single Blocks (*continued*)

ID	Shell								Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Strop type	Dia. (mm)	Thick-ness (mm)	Wood Species	Length (mm)	Dia. (mm)
18872	31	ash	202	136	71	16	26	rope	120	25	ash	74	25
14897	31	oak	203	139	76	14	21	rope	133	27	ash	71	29
08893	31	oak	205	143	68	14	22	rope	130	28	ash	74	25
18987	31	oak	206	139	71	20	22	rope	134	28	ash	76	27
04154	31	ash	212	144	71	16	26	rope	139	25	ash	76	36
12523	31	oak	222	146	80	eroded	23	rope	144	27	ash	79	26
09647	31	oak	240	140	69	12	22	rope	123	25	oak	75	23
00711	31	ash	245	174	81	17	unknown	rope	164	29	ash	82	33
21716	32	ash	175	122	66	15	20	rope	119	23	ash	69	25
10527	32	ash	182	117	59	eroded	unknown	rope	112	22	ash	64	24
14611	32	oak	184	130	70	eroded	unknown	rope	123	24	ash	72	27
19250	32	oak	185	126	70	eroded	unknown	rope	117	25	ash	75	25
21740	32	ash	190	120	67	13	22	rope	115	26	ash	70	25
13743	32	oak	191	130	73	eroded	22	rope	126	26	ash	76	25
08454	32	oak	201	132	76	eroded	22	rope	129	27	ash	80	26
00125	32	ash	203	145	70	eroded	25	rope	128	26	ash	72	29
19903	32	oak	203	139	80	16	25	rope	129	28	ash	84	26
NN14	32	oak	205	148	72	18	23	rope	138	27	ash	81	24
10578	32	oak	206	137	80	eroded	22	rope	missing	missing	missing	missing	missing
11130	32	ash	206	127	80	16	22	rope	133	25	ash	74	26
00253	32	ash	208	130	72	eroded	23	rope	125	28	ash	76	32
11483	32	oak	208	140	72	14	23	rope	138	27	ash	76	25
18871	32	oak	208	139	78	17	25	rope	145	27	ash	82	26
08452	32	oak	210	138	80	16	24	rope	135	28	ash	85	27
10579	32	oak	210	135	78	17	30	rope	136	27	ash	79	26
19902	32	oak	212	146	79	15	24	rope	137	28	ash	84	27
03530	32	oak	213	150	75	eroded	28	rope	141	27	ash	79	25
08522	32	oak	217	142	74	15	21	rope	138	28	ash	82	27
09637	32	ash	217	157	75	eroded	28	rope	143	28	ash	75	29
11098	32	oak	217	155	78	18	27	rope	153	29	ash	80	31
18905	32	oak	218	135	80	15	19	rope	130	26	ash	83	26
10814	32	oak	220	146	79	eroded	30	rope	136	26	ash	83	28
11645	32	oak	222	156	85	eroded	23	rope	140	27	ash	86	26
11108	32	ash	228	152	78	15	24	rope	146	28	ash	80	28
15726	32	oak	247	175	79	20	32	rope	163	27	ash	85	31
20532	33	oak	175	114	63	12	20	rope	104	26	ash	69	27
21736	33	oak	179	113	63	eroded	23	rope	107	23	ash	64	22
23147	33	ash	188	125	68	13	24	rope	111	24	ash	68	27
08455	33	oak	201	140	72	eroded	23	rope	129	29	ash	74	27
08459	33	oak	201	xx	80	17	unknown	rope	missing	missing	missing	missing	missing
12889	33	ash	202	129	69	eroded	24	rope	113	28	ash	71	28
20708	33	ash	203	132	66	17	25	rope	122	27	ash	67	27
11055	33	oak	205	138	78	18	23	rope	133	27	ash	81	24
14588	33	ash	205	148	79	19	27	rope	139	28	ash	83	31
03461	33	oak	211	145	76	eroded	29	rope	136	25	ash	81	26
12336	33	oak	212	154	77	17	27	rope	150	28	ash	79	31
10715	33	oak	213	137	76	eroded	26	rope	130	28	ash	80	28
04126	33	oak	216	136	85	15	21	rope	140	27	ash	86	24
NN03	33	oak	216	133	82	19	22	rope	139	27	ash	broken	26
12524	33	oak	217	147	80	eroded	22	rope	139	28	ash	84	27
13878	33	oak	217	154	73	16	22	rope	139	28	ash	missing	missing

Sub-Type 1 Single Blocks (*continued*)

ID	Shell								Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Strop type	Dia. (mm)	Thick-ness (mm)	Wood Species	Length (mm)	Dia. (mm)
11598	33	ash	219	149	67	15	24	rope	137	27	ash	69	29
10179	33	ash	220	143	80	16	24	rope	144	25	ash	missing	missing
10585	33	oak	220	145	82	eroded	24	rope	139	27	ash	86	27
11198	33	oak	220	151	81	19	30	rope	146	30	ash	84	30
11597	33	oak	220	146	75	16	26	rope	138	27	ash	80	25
07852	33	ash	221	156	79	eroded	26	rope	137	31	ash	78	27
13714	33	oak	221	146	78	15	25	rope	142	29	ash	missing	missing
18985	33	oak	229	153	78	14	26	rope	147	28	ash	82	31
03849	33	oak	230	155	75	19	30	rope	140	24	ash	78	25
23499	33	ash	232	160	81	eroded	29	rope	142	27	ash	80	32
09928	34	oak	192	130	65	eroded	23	rope	125	27	ash	71	28
NN55	34	oak	196	128	67	15	20	rope	124	26	ash	missing	missing
08688	34	ash	204	135	67	15	26	rope	118	26	ash	70	24
15764	34	oak	208	142	83	18	22	rope	137	28	ash	85	28
13391	34	ash	210	145	82	18	20	rope	137	29	ash	85	28
08163	34	ash	211	141	70	eroded	24	rope	127	27	ash	72	26
09502	34	oak	215	146	77	eroded	25	rope	137	28	ash	81	25
11550	34	oak	216	156	75	eroded	24	rope	140	27	ash	missing	missing
04347	34	oak	218	145	75	eroded	34	rope	137	29	ash	missing	missing
23139	34	ash	224	154	76	17	29	rope	142	28	ash	78	28
12377	34	oak	230	146	80	15	25	rope	138	28	ash	82	27
03657	34	ash	238	160	80	17	29	rope	155	31	ash	83	32
16844	34	oak	240	172	77	14	29	rope	155	28	ash	82	30
14801	34	oak	248	173	86	17	28	rope	163	28	ash	85	31
19198	35	oak	188	116	69	14	25	rope	114	26	ash	73	27
23520	35	ash	196	132	69	14	24	rope	116	27	ash	70	26
08614	35	oak	203	145	72	17	25	rope	134	28	ash	76	24
13586	35	oak	216	139	85	14	24	rope	136	27	ash	87	26
18910	35	ash	217	147	76	20	24	rope	142	29	ash	80	27
08652	35	ash	218	144	75	16	23	rope	144	28	ash	79	26
19723	35	oak	218	153	82	18	28	rope	147	30	ash	81	27
20707	35	ash	218	143	73	15	24	rope	130	27	ash	75	28
07660	35	oak	221	148	76	19	28	rope	140	28	ash	80	27
11170	35	oak	222	145	77	eroded	unknown	rope	180	35	ash	84	30
15712	35	ash	222	170	83	17	28	rope	156	28	ash	86	31
03748	35	oak	223	152	80	15	25	rope	145	26	ash	82	30
07702	35	oak	225	154	77	eroded	27	rope	143	28	ash	83	27
09501	35	ash	226	154	82	17	26	rope	152	27	ash	missing	missing
03207	35	oak	230	149	82	16	24	rope	141	28	ash	broken	26
17945	35	oak	230	164	81	20	28	rope	151	31	ash	88	32
09509	35	oak	231	158	81	16	31	rope	156	30	ash	86	30
17987	35	oak	232	157	80	16	31	rope	152	30	ash	83	27
14587	35	ash	236	149	88	20	28	rope	147	29	ash	90	27
08389	35	ash	248	169	83	16	31	rope	157	28	ash	84	31
15374	35	oak	248	180	85	15	32	rope	161	27	ash	88	32
14896	35	ash	252	181	82	19	29	rope	175	27	ash	91	32
20791	35	ash	258	165	80	18	unknown	rope	152	26	ash	86	32
07118	35	oak	236	155	72	10	28	rope	141	23	ash	74	28
NN13	36	oak	192	128	72	eroded	unknown	rope	123	25	ash	missing	missing
11429	36	oak	209	134	76	eroded	25	rope	134	29	ash	80	25
12324	36	ash	210	147	77	eroded	unknown	rope	141	30	ash	83	31

Sub-Type 1 Single Blocks (*continued*)

ID	Shell								Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Strop type	Dia. (mm)	Thick-ness (mm)	Wood Species	Length (mm)	Dia. (mm)
09346	36	oak	211	144	76	17	25	rope	143	31	ash	80	29
08194	36	oak	216	150	78	19	25	rope	143	29	ash	84	25
13393	36	ash	222	142	73	16	23	rope	142	31	ash	75	27
07859	36	ash	224	130	76	14	27	rope	126	30	ash	82	29
10884	36	oak	224	144	84	17	27	rope	139	30	ash	87	28
03300	36	oak	226	146	88	18	29	rope	143	27	ash	91	28
08457	36	ash	227	144	88	17	25	rope	142	28	ash	92	27
12591	36	oak	230	152	90	18	29	rope	146	28	ash	92	26
20792	36	ash	231	155	80	18	28	rope	150	30	ash	80	30
07659	36	oak	235	150	88	16	27	rope	144	29	ash	88	31
11115	36	oak	240	162	87	20	23	rope	155	29	ash	92	31
03962	36	ash	245	174	82	20	unknown	rope	153	28	ash	84	30
07710	36	oak	247	161	92	19	26	rope	153	30	ash	94	31
15280	36	ash	273	165	98	19	39	rope	158	36	ash	98	36
11327	37	oak	208	138	86	15	23	rope	138	27	ash	88	25
12420	37	oak	222	148	79	18	25	rope	134	29	ash	82	29
23498	37	ash	232	162	86	17	29	rope	151	32	ash	89	30
04195	37	oak	240	167	88	18	32	rope	156	30	ash	92	27
15259	37	oak	240	171	77	15	32	rope	159	33	ash	85	33
10569	37	oak	242	158	84	eroded	27	rope	156	30	ash	87	32
03664	37	oak	246	155	87	eroded	25	rope	154	27	ash	89	30
23137	37	ash	249	157	82	17	27	rope	149	39	ash	86	31
04346	37	ash	251	165	83	18	29	rope	164	31	ash	84	33
14895	37	ash	260	180	81	13	29	rope	170	29	ash	82	30
23283	38	oak	230	148	75	20	26	rope	130	29	ash	78	26
01771	38	ash	235	157	74	12	24	rope	141	28	ash	79	28
23144	38	ash	243	160	73	14	unknown	rope	148	30	ash	76	30
21724	38	ash	254	165	81	19	30	rope	152	32	ash	86	34
23143	38	oak	260	159	92	22	28	rope	157	33	ash	96	31
18719	39	oak	207	145	74	14	32	rope	135	29	ash	83	29
11594	39	oak	216	149	80	16	23	rope	143	29	ash	83	28
16735	39	ash	236	171	85	14	30	rope	missing	missing	missing	77	32
17093	39	ash	243	161	81	eroded	31	rope	143	28	ash	84	32
00141	39	ash	244	163	76	eroded	31	rope	146	28	ash	74	33
04125	39	oak	249	172	86	19	29	rope	158	30	ash	90	26
00140	39	oak	250	165	84	20	30	rope	154	27	ash	89	30
08613	39	ash	287	190	88	eroded	unknown	rope	192	33	ash	92	35
09611	40	oak	243	177	88	18	31	rope	160	30	ash	93	31
15251	40	ash	252	177	86	18	38	rope	152	32	ash	87-broken	32
08982	40	ash	262	187	86	21	29	rope	169	30	ash	91	30
07921	41	oak	223	151	89	18	28	rope	152	30	ash	91	30
10597	41	ash	227	159	80	16	26	rope	142	30	ash	83	32
00303	41	oak	245	149	85	17	23	rope	167	25	ash	80	29
23116	41	ash	265	170	96	20	27	rope	176	30	ash	103	36
08191	42	oak	243	161	87	17	28	rope	162	29	ash	81	31
15597	42	ash	273	157	94	eroded	34	rope	154	36	ash	95	38
20310	42	ash	292	215	94	20	35	rope	192	31	ash	95	37
11659	43	ash	276	187	94	23	27	rope	171	34	ash	92	38
23358	43	ash	295	209	87	eroded	34	rope	190	30	ash	94	35
04205	44	ash	307	212	103	23	40	rope	213	34	ash	107	41
00962	46	ash	298	212	92	20	31	rope	188	33	ash	95	37

Sub-Type 1 Single Blocks (*continued*)

ID	Shell								Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Strop type	Dia. (mm)	Thick-ness (mm)	Wood Species	Length (mm)	Dia. (mm)
19904	49	ash	308	180	113	21	29	iron	missing	missing	missing	missing	missing
10528	49	ash	234	129	93	eroded	unknown	rope	129	18	ash	96	28
19906	50	ash	357	236	119	27	32	iron	195	45	ash	220	47
00112	80	ash	478	302	161	40	65	iron	missing	missing	missing	missing	34
20526	87	oak	480	289	183	33	59	iron	missing	missing	missing	missing	missing
20517	90	ash	480	310	200	39	64	iron	missing	missing	missing	missing	missing
03656	90	birch	480	295	150	39	69	rope	277	60	ash	169	52
06447	unknown	ash	159	113	xx	eroded	21	rope	99	22	ash	61	21
15254	unknown	ash	159	109	xx	eroded	unknown	rope	missing	missing	missing	67	23
08167	unknown	ash	172	113	xx	eroded	unknown	rope	missing	missing	missing	67	28
00406	unknown	ash	174	105	60	eroded	unknown	rope	97	20	ash	65	22
11420	unknown	ash	174	115	62	eroded	19	rope	106	24	ash	66	27
15725	unknown	oak	175	118	66	14	19	rope	116	24	ash	69	27
04017	unknown	oak	179	121	xx	eroded	22	rope	106	24	ash	70	24
17992	unknown	oak	180	130	xx	eroded	unknown	rope	129	30	ash	70	25
10001	unknown	oak	181	130	xx	eroded	24	rope	115	25	ash	missing	missing
12544	unknown	oak	196	137	66	eroded	unknown	rope	129	28	ash	74	26
08165	unknown	oak	198	119	xx	eroded	unknown	rope	117	25	ash	68	24
11271	unknown	oak	204	142	xx	eroded	unknown	rope	118	22	ash	58	24
13859	unknown	oak	205	140	xx	eroded	unknown	rope	125	26	ash	80	24
08390	unknown	ash	216	146	xx	eroded	unknown	rope	132	25	ash	63	30
13745	unknown	oak	222	144	75	eroded	unknown	rope	136	25	ash	80	27
14899	unknown	oak	230	162	xx	eroded	28	rope	164	27	ash	89	30

Five of the larger examples of these blocks with chamfered elliptical shells were modified to serve as hook blocks. Their strop scores were squared out with chisels and an iron strop with a large hook forged at one end was fitted around the block. The three largest of these hook blocks (Fnrs 20517, 20526, & 00112) were actually recovered with their corroded iron hooks still intact (Figure 6.10). Another unique *sub-type 1* single block (Fnr 03656) has a birch shell. It is one of just a handful of birch blocks from the entire ship. Its ash sheave and wooden axle, however, are fashioned in the same manner as the other *sub-type 1* single blocks found in association with *Vasa*.

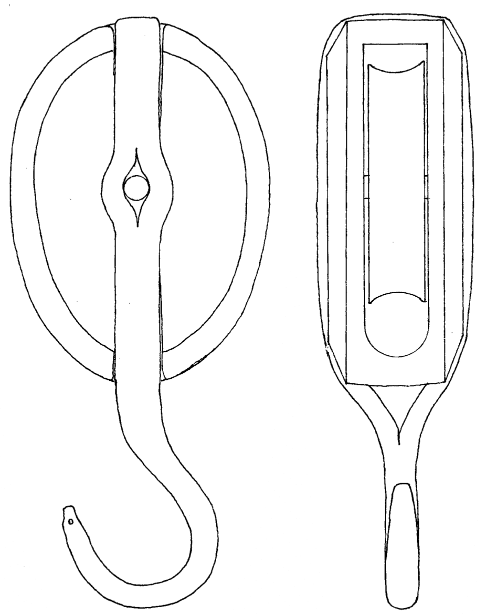


FIGURE 6.10. *Sub-type 1* single block with its iron strop and hook (Drawing by Nathaniel Howe, 2011).

Sub-type 2. Piriform with Rounded Edges and Squared-Off Ends. The second most common sub-type among *Vasa*'s single blocks features a piriform shell (pear- or drop-shaped) that is squared off at both ends and has edges that are rounded instead of chamfered (Figure 6.11). Although only 12 of these blocks and one readily identifiable fragment of another survived, this comparatively small group shows considerable variation in size (Table 6.3). Swallows appear in six distinct sizes ranging from 25mm to 55mm (25-, 35-, 40-, 55mm) and shell lengths span from 143mm up to 398mm. The extant examples do not reflect usage of a pattern in cutting the shells as no two examples of this style are the same size, but there are too few to be sure of this. The shells of these blocks are all made of ash except for three of the smallest examples, all under 160mm long, that are made of oak (Fnrs 23135, 23086, & NN26).

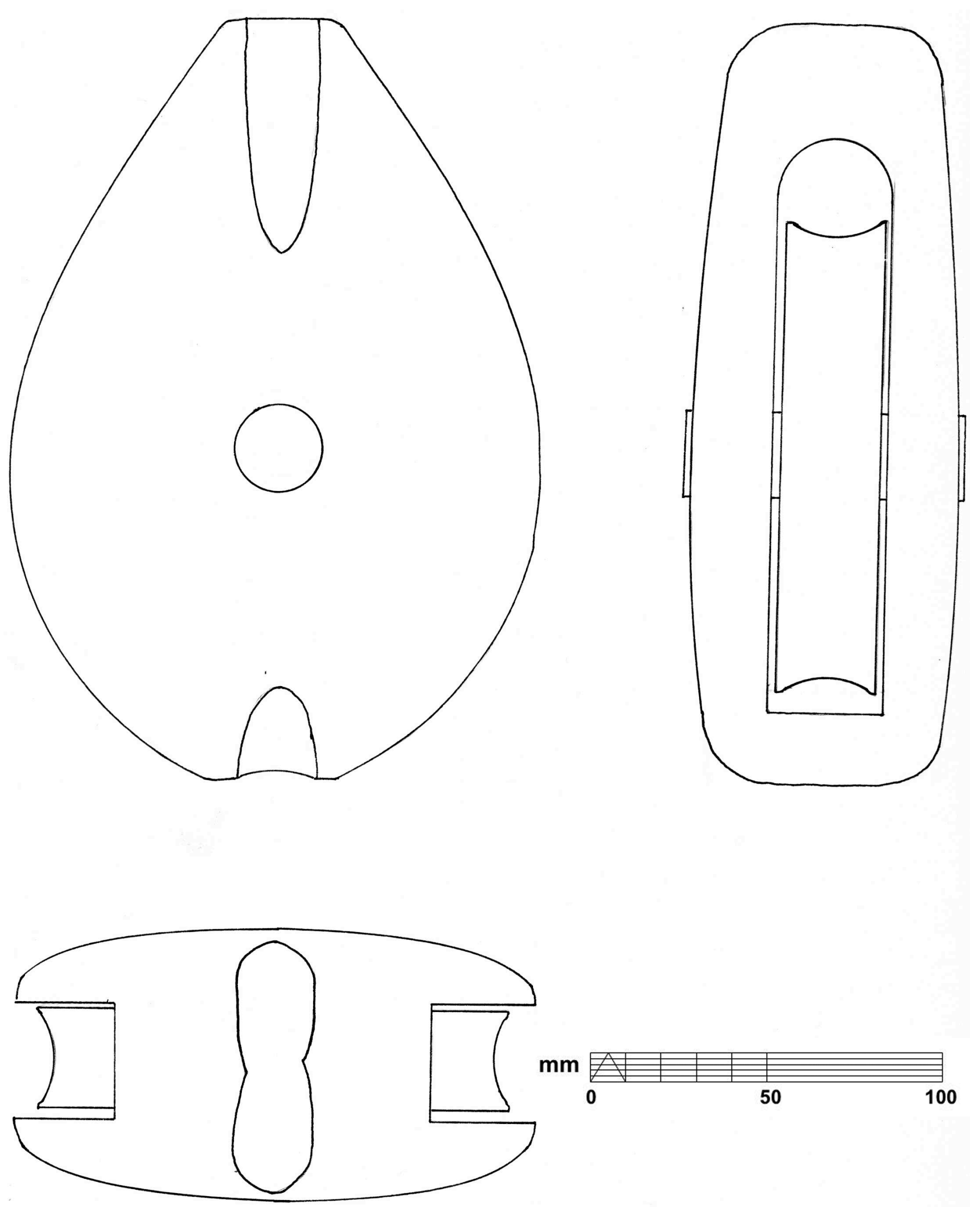


FIGURE 6.11. *Sub-type 2* single block with a piriform shell, rounded edges, and squared off ends (Illustrated by Nathaniel Howe, 2011).

Sub-Type 2 Single Blocks

ID	Shell						Sheave			Axle	
Find Nr	Swallow diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Diameter (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
23135	23	oak	150	94	69	19	86	20	ash	71	22
23086	24	oak	148	103	58	17	82	19	ash	59	23
07714	24	ash	151	109	57	14	80	16	ash	63	18
23148	27	ash	174	127	72	23	105	24	ash	74	22
20709	34	ash	256	174	106	32	152	29	ash	110	32
18628	35	ash	387	304	118	43	265	29	ash	129	39
21738	38	ash	253	154	95	32	149	32	ash	97	32
NN09	38	ash	264	173	97	35	166	33	ash	106	34
10521	39	ash	262	182	100	35	170	32	ash	105	32
23136	55	ash	398	269	130	45	238	46	ash	142	42
NN26	unknown	oak	143	88	unknown	unknown	74	16	ash	67	23
07688	unknown	ash	256	185	66	unknown	157	33	ash	111	35
12417	unknown	ash	253	187	52	30	missing	missing	missing	missing	36

TABLE 6.3. *Sub-type 2* single blocks organized by swallow diameter (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 3. Piriform with Rounded Edges. There are four other piriform blocks with rounded edges that differ in form just enough to constitute a third style. These three blocks are virtually identical to *sub-type 2* single blocks except that rather than having their ends cut off square, their ends are rounded to complete the curves (Figure 6.12). One of these blocks is oak (Fnr 17850), two are ash (Fnrs 00991 & 04134), and the fourth (Fnr 00407), which is badly deteriorated, appears to be made from yet another species. All are relatively small blocks. Find number 04134 is 236mm overall, but the other three blocks are only 111-140mm, being cut to handle cordage of less than 20mm in diameter (Table 6.4).

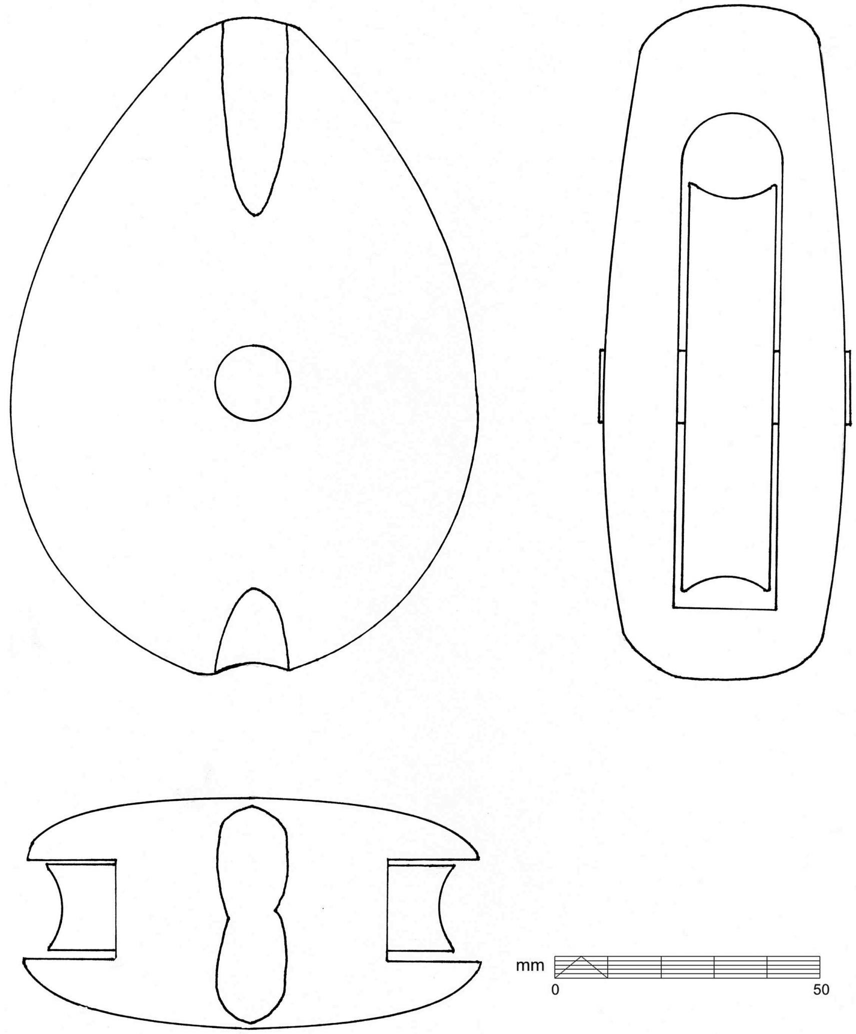


FIGURE 6.12. *Sub-type 3* single block with a piriform shell and rounded edges and ends (Drawn by Nathaniel Howe, 2011).

Sub-Type 3 Single Blocks

ID	Shell						Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood Species	Length (mm)	Dia. (mm)
00407	19	unknown	111	75	48	unknown	60	11	unknown	52	13
00991	22	ash	140	95	53	unknown	missing	missing	missing	64	19
04134	38	ash	236	160	86	30	157	23	ash	92	31
17850	unknown	oak	122	88	xx	unknown	85	21	ash	61	22

TABLE 6.4. *Sub-type 3* single blocks organized by swallow diameter (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 4. Broad, Flat, Lenticular Blocks. The fourth style of single block consists of six large blocks that are broad and flat with a lenticular profile and very thin cheeks (Figure 6.13). On average, they are 480mm long and almost as wide, but they are only 120mm thick. These dimensions make for proportionally thin block with a length-to-thickness ratio of about 4:1 instead of the usual 2.2:1 seen in a standard *Vasa* single block. The swallows of these large, flat blocks range from 43mm to 60mm and overall shell lengths span 423mm to 498mm (Table 6.5). These blocks (Fnrs 20518, 23466, 17930, 11782, 00114, and NN54) are a specialized and somewhat delicate sub-type.

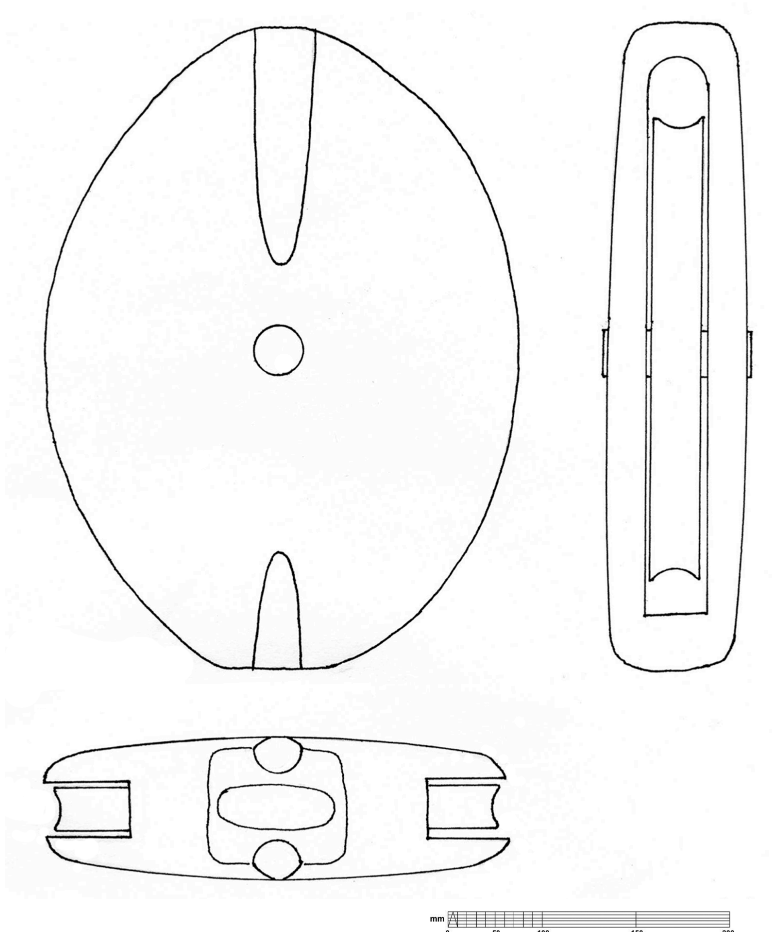


FIGURE 6.13. *Sub-type 4* single block with flat lenticular shell and rounded edges (Drawn by Nathaniel Howe, 2011).

Sub-Type 4 Single Blocks

ID	Shell						Sheave			Axle	
Find Number	Swallow diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
17930	43	ash	423	320	105	40	296	31	ash	100	38
00114	45	ash	445	359	101	41	338	28	ash	102	41
11782	48	ash	486	372	114	36	363	30	ash	119	39
23466	50	ash	490	379	125	40	357	32	ash	132	38
NN54	55	ash	481	366	128	38	352	33	ash	133	40
20518	60	ash	498	362	117	42	350	37	ash	120	40

TABLE 6.5. *Sub-type 4* single blocks organized by swallow diameter (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 5. Dutch Lift Blocks. The fifth style is markedly different in form. This type has an elongated rectangular shell with convex sides. One sheave is set into the middle of the block and eyeholes are bored through each end of the shell perpendicular to the plane of the sheave (Figure 6.14). The seven blocks of this type from *Vasa* are almost identical to the classic Dutch-style upper lift block (Anderson 1927:145). They are cut with 30mm, 35mm, and 40mm swallows (Table 6.6).

At first these double-ended blocks appear to be symmetrical, but closer inspection reveals that they have a distinct head and foot. The sheave mortise is cut flat on one end and curved at the other to create the swallow, thereby allowing the fall to pass only through one end of the block. Additionally, the two eyeholes in the ends of the shell are different diameters with the larger of the two being toward the head. This eyehole was for the heavy pendant from the mast. The smaller hole took the standing end of the fall as described in the discussion of the blocks of the squaresail running rig.

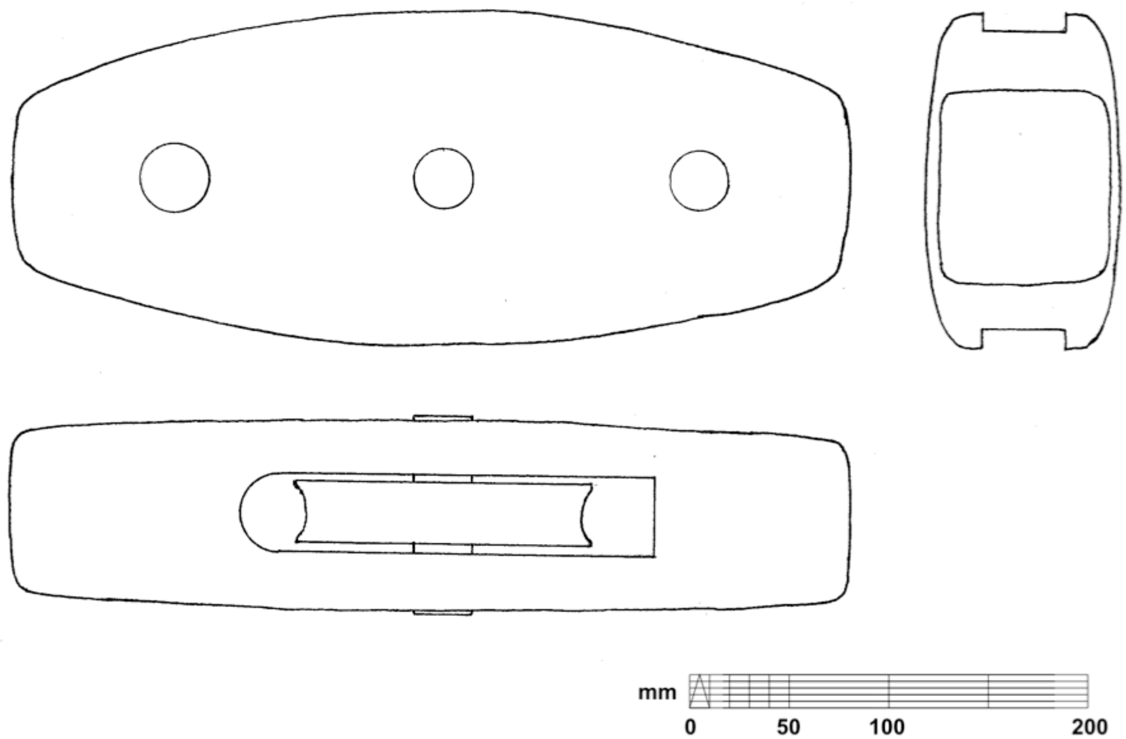


FIGURE 6.14. *Sub-type 5* single block. Note the hole on the left is larger in order to secure the pendant. The hole on the right is slightly smaller for securing the standing end of the lift (Drawing by Nathaniel Howe, 2011).

Sub-Type 5 Single Blocks

ID	Shell							Sheave			Axle	
Find Number	Swallow diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Pendant fastening (mm)	Fall fastening (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
20000	27	birch	379	88	69	unknown	28	101	25	ash	80	22
19717	28	ash	365	144	75	unknown	29	138	25	ash	77	30
18901	33	ash	336	119	74	41	37	109	25	ash	75	23
21454	34	ash	427	167	88	38	31	160	27	ash	96	29
04348	34	ash	433	164	98	38	30	156	27	ash	94	28
20527	38	ash	425	164	90	43	37	151	30	ash	91	29
03741	39	ash	424	169	97	38	31	149	26	ash	102	31

TABLE 6.6. *Sub-type 5* single blocks organized by swallow diameter (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

All of these classic Dutch upper lift blocks are made of ash except for one that is made of birch (Fnr 20000). This block appears to have been hastily made by someone who was clearly not one of the master craftsmen in the block shop. It is crudely carved (possibly with just the rigger's own sheath knife) with little attention to neatness or symmetry. In addition to being made of birch, it is also the only block of this sub-type with chamfered edges—the rest are rounded to reduce chafing.

The sheaves in all seven of these blocks are lathe-turned and made of ash. One of them (Fnr 21454) actually has clearly visible lathe marks all the way to the centre of each sheave face.

<u>Sub-types 6, 7, and 8. Oblong Single Blocks</u>. The sixth, seventh, and eighth styles are very similar. Combined, they consist of 13 blocks that all have oblong elliptical shells, and rounded edges (Figure 6.15). The *sub-type 6* single blocks have squared-off ends. The two largest blocks in this group (Fnrs 09149 and 04078) were fitted with iron strops to absorb heavy loads as hook blocks.

The two blocks constituting *sub-type 7* are slightly different and therefore—although very similar—are best classified as a separate style. These blocks (Fnrs 20327 & 03670) are identical except that the ends of the shell have not been squared off.

Another very similar pair of blocks (Fnrs 08386 & 15714) are also sufficiently different to constitute a separate sub-type. Instead of smoothly rounded edges these feature chamfered edges, but are otherwise made to the same proportional specifications. Their swallows vary between 44mm and 50mm in width and their shell lengths range by only 8mm (Table 6.7). The smallest of these (Fnr 15714) has a shell-to-strop-score ratio of about 6.5:1 instead of the usual 7.5:1 seen in the vast majority of the *Vasa* single blocks.

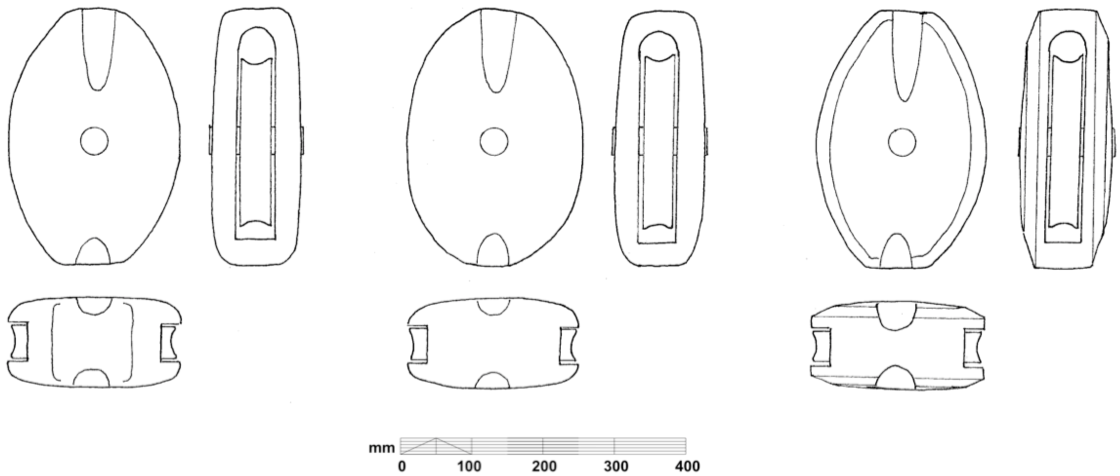


FIGURE 6.15. *Sub-type 6, 7, & 8* single blocks (Drawing by Nathaniel Howe, 2011).

Sub-Type 6, 7, and 8 Single Blocks

ID		Shell								Sheave			Axle	
Find Number	Sub-type	Swallow diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Strop type	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
07889	6	38	ash	269	189	107	rounded	39	rope	179	33	ash	112	37
05407	6	39	ash	230	158	80	rounded	32	rope	151	20	ash	85	31
15328	6	43	ash	241	169	92	rounded	31	rope	146	28	ash	95	33
20796	6	60	ash	385	265	138	rounded	44	rope	245	44	ash	146	47
04078	6	62	ash	460	311	165	rounded	48	iron	286	58	ash	173	56
09149	6	65	ash	543	341	186	rounded	47	iron	337	63	unknown	177	52
3236a	6	69	ash	398	265	140	rounded	49	rope	missing	missing	missing	missing	48
23465	6	73	ash	525	338	154	rounded	57	rope	300	60	ash	167	47
23078	6	82	ash	506	332	178	rounded	53	rope	293	48	ash	185	53
03670	7	55	oak	445	312	129	rounded	40	rope	321	36	ash	missing	46
20327	7	58	ash	334	231	119	rounded	33	rope	190	41	ash	122	39
08386	8	44	ash	298	159	95	30	28	rope	130	34	ash	95	30
15714	8	50	ash	290	166	96	18	44	rope	185	35	ash	101	34

TABLE 6.7. *Sub-type 6, 7, and 8* single blocks organized by swallow diameter (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 9. Pendant Blocks. Another highly distinctive type of single block appears in the form of a trio of pendant blocks—possibly crane blocks. These have pear-shaped shells with a sheave set into the broader portion and an eyehole through the narrower portion, bored perpendicular to the plane of the sheave (Figure 6.16). Three single-sheaved examples of this type were recovered. All of them are carved from ash with smooth, rounded edges and have sheaves made of ash. Swallow diameters appear in two sizes, one block having a 43mm swallow (Fnr 19905) and the other two (Fnrs 23117 & 03016) averaging 55mm (Table 6.8). Evidence of use can actually be seen on Find Number 03016 while Find Number 19905 has some of the finest examples of tool marks of any block in the collection. All of these were slab-cut close to the heartwood, the first year's growth ring running down the outside of one cheek.

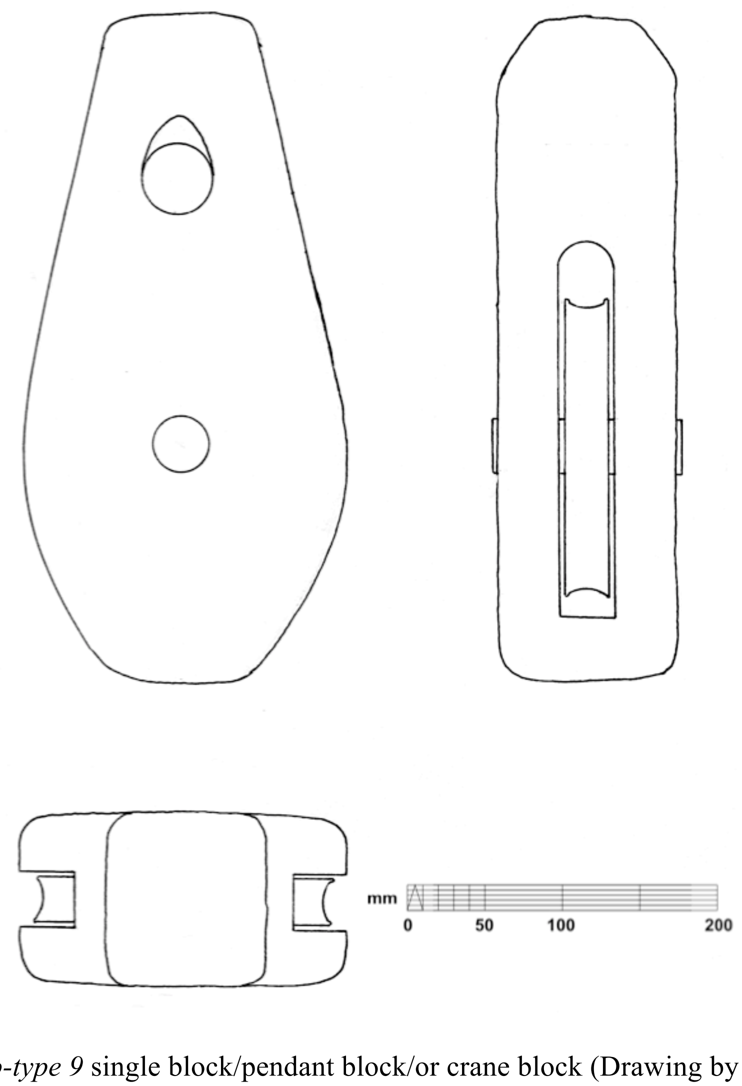


FIGURE 6.16. *Sub-type 9* single block/pendant block/or crane block (Drawing by Nathaniel Howe, 2011).

Sub-Type 9 Single Blocks

ID	Shell						Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Pendant size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
19905	38	ash	406	205	122	43	197	34	ash	125	37
03016	42	ash	484	227	130	55	213	30	ash	139	36
23117	45	ash	398	210	110	57	176	36	ash	119	31

TABLE 6.8. *Sub-type 9* single blocks organized by swallow diameter (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

<u>Sub-type 10. Heavy Duty Single Block.</u> Another variation on the oblong single block is a pair of very solidly made blocks with rounded edges and very thick cheeks (Fnrs 00688 & 23504) (Figure 6.17). Most single blocks from the ship have sheave mortises approximately 15% wider than the thickness of each cheek. These two, however, reverse that ratio, the cheeks being thicker than the sheave mortise by almost 20%. Both blocks have 40mm swallows and an overall length just shy of 310mm (Table 6.9). Find Number 23504 was cut to include the heartwood and consequently split rather badly after recovery.

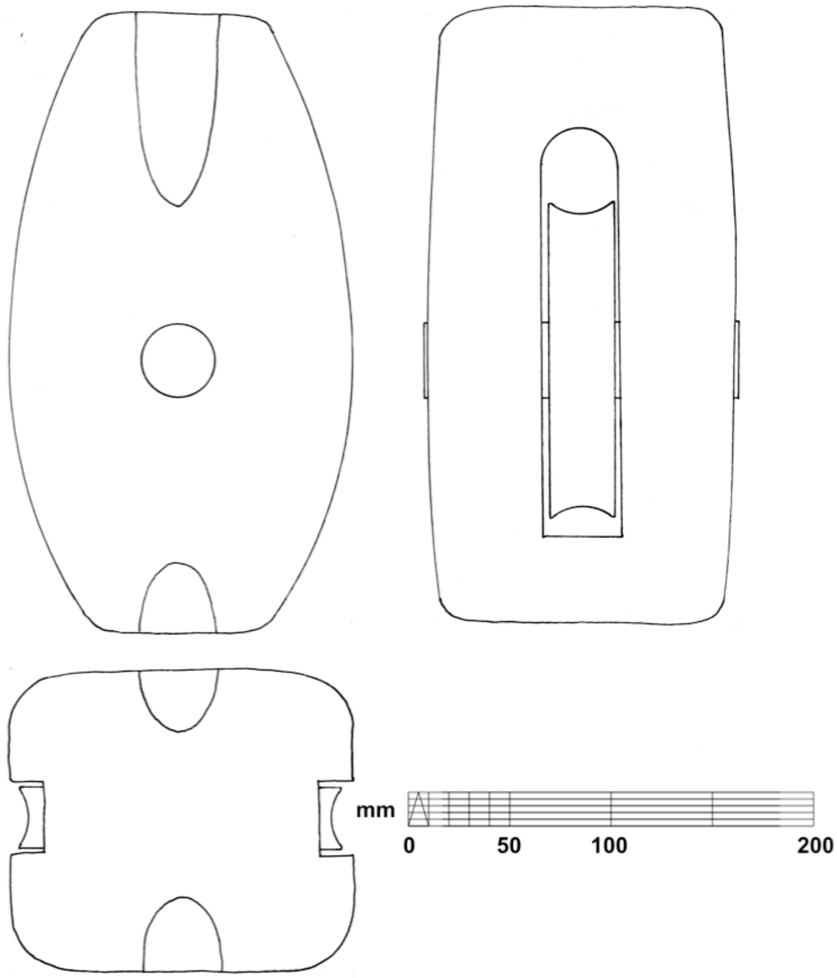


FIGURE 6.17. *Sub-type 10* single block (Drawing by Nathaniel Howe, 2011).

Sub-Type 10 Single Blocks

ID	Shell							Sheave			Axle	
Find Number	Sub-Type	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
23504	10	38	ash	309	172	153	37	157	31	ash	150	37
00688	10	42	ash	306	187	139	35	172	33	ash	140	36

TABLE 6.9. List of the *sub-type 10* single blocks recovered with *Vasa* organized by swallow size (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 11. Seventeenth-Century Snatch Block. Perhaps the most specialized style of single block found with *Vasa* is a 17^{th} century snatch block (Figure 6.18). This is easily recognized by a gap in the shell cut through one side of the swallow to allow the fall to be laid in or taken out of the block without reeving it through from the bitter end. The snatch block is a bulky 832mm-long oak block made with a 72mm swallow (Fnr 08692). There is no indication that it ever carried any metal parts or fittings. It was secured by means of a pendant or collar fastened through a large 70mm eyehole in the head of the block (Table 6.10). The entire block has 23mm chamfered edges and no visible signs of usage. Unfortunately, the sheave for this unique block is missing.

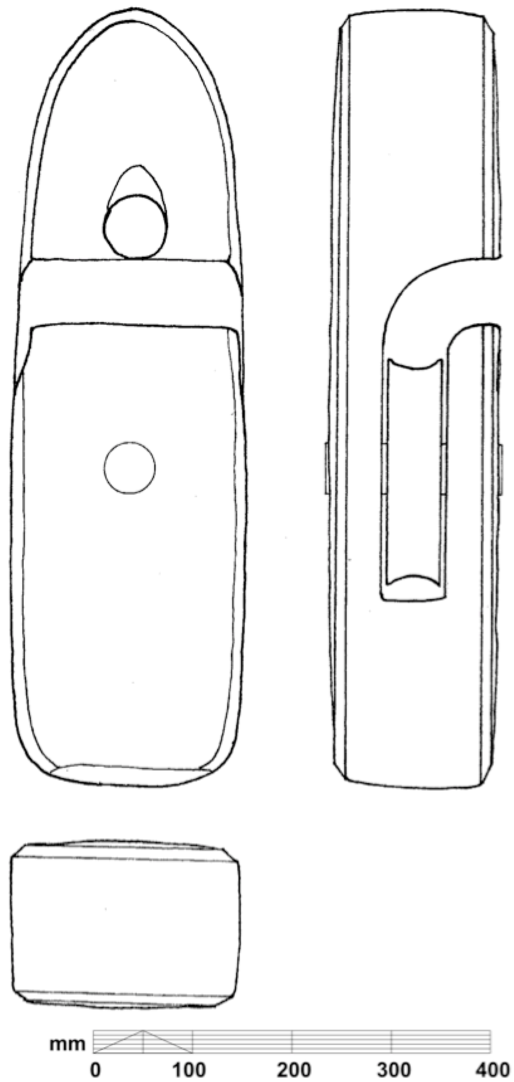


FIGURE 6.18. *Sub-type 11* single block, or snatch block (Drawing by Nathaniel Howe, 2011).

Sub-Type 11 Single Block

ID	Shell						Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
08692	72	oak	832	249	181	70	missing	missing	missing	missing	61

TABLE 6.10. The *sub-type 11* single block recovered with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

<u>Sub-type 12 single block. 18th-19th century snatch block.</u> A second snatch block (Fnr 20746), matching 18th and 19th century patterns, was also found in association with *Vasa*. It is made of ash, has a *lignum vitae* sheave, and still has its forged iron stop complete with a hinged clasp to enclose the swallow (Figure 6.19). The overall dimensions of this block are only partially obtainable as the block is broken just opposite the opening in the side of the swallow. However, the 27mm-thick sheave can attest to the mid-size cordage carried by this block (Table 6.11).

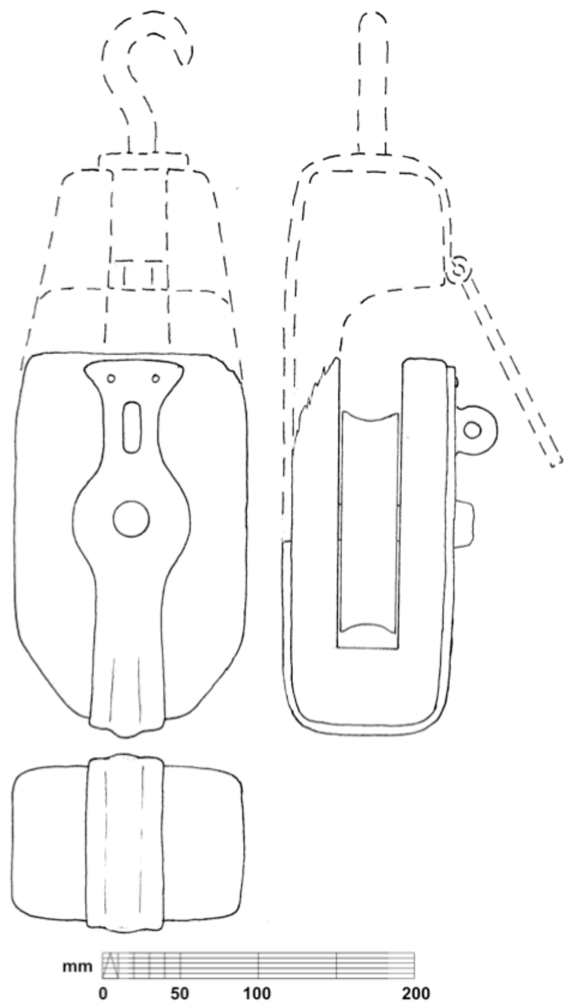


FIGURE 6.19. *Sub-type 12* single block. 18th-19th century snatch block (Drawing by Nathaniel Howe, 2011).

Sub-Type 12 Single Block

ID	Shell						Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
20746	43	ash	239	151	101	51	140	34	*lignum vitae*	missing	26

TABLE 6.11. The *sub-type 12* single block recovered with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

<u>Sub-type 13. Elliptical block with crisp edges and equal-length strop scores.</u> A particularly unique single block is a lone example (Fnr 20624) with an elliptical shell, crisp edges, and upper and lower strop scores of equal length (Figure 6.20). In form, it is significantly different from the other blocks found in association with *Vasa*, having no chamfering or the characteristic asymmetrical strop scores. It is also converted differently with the pith running up through the body of the shell. It is 190mm long with a swallow cut for 28mm-30mm cordage (Table 6.12).

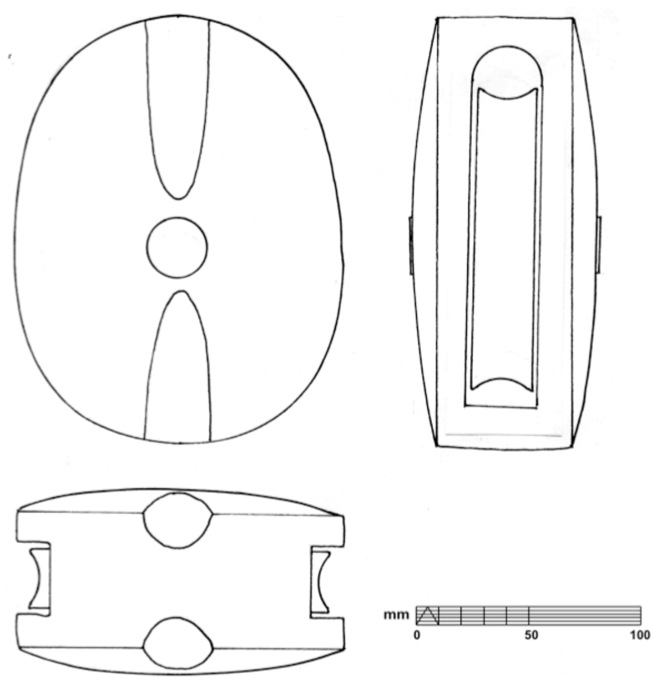


FIGURE 6.20. The lone *sub-type 13* single block (Drawing by Nathaniel Howe, 2011).

Sub-Type 13 Single Block

ID	Shell						Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
20624	30	ash	190	146	81	29	missing	missing	missing	missing	20

TABLE 6.12. The *sub-type 13* single block recovered with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 14. Laminated block. The last distinctive type of single block recovered with *Vasa* is a more modern block 'made block' with a laminated wooden shell (Figure 6.21) still fastened together with iron rivets—the survival of the iron attesting to its relative youth (Fnr NN08). It has no strop score of any kind and would have been difficult to rig in any capacity. The sheave and axle are missing, but the small diameter axle hole bored through the shell indicates that it almost certainly carried an iron or steel axle (Table 6.13).

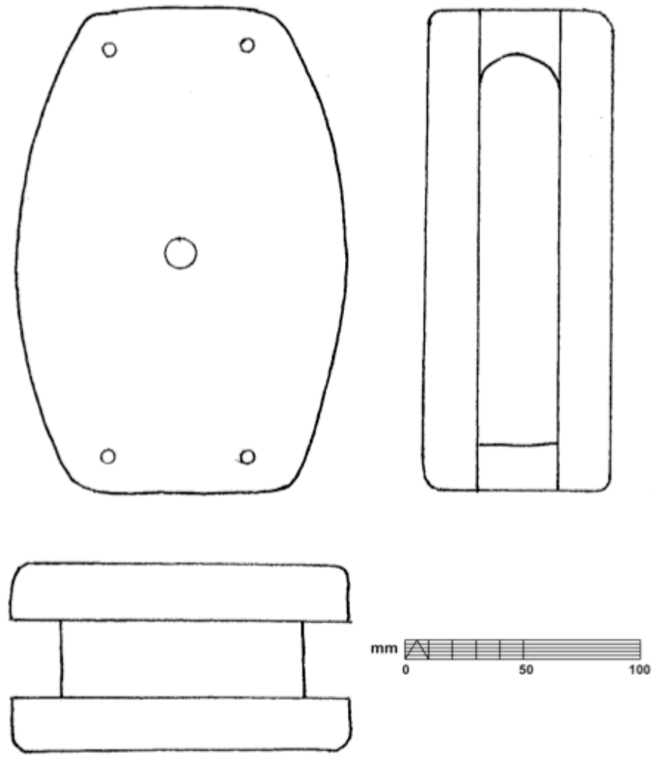


FIGURE 6.21. *Sub-type 14* single block (Drawing by Nathaniel Howe, 2011).

Sub-Type 14 Single Block

ID	Shell						Sheave			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
NN08	32	unknwn	202	141	81	none	missing	missing	missing	missing	12

TABLE 6.13. The *sub-type 14* single block recovered with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Double Sheaved Blocks

A total of 114 double-sheaved blocks of all kinds were recovered with *Vasa*. These consist of six major sub-types. Three of the sub-types, comprising the majority of the double blocks, have sheaves set side-by-side. The other three sub-types have end-to-end sheave arrangements including one that has its sheaves set 90° to one another.

Sub-type 1. Elliptical with chamfered edges. The bulk of the double block collection consists of just one style. These blocks have sheaves of equal size arranged side-by-side and in the same plane. The shells are elliptical with chamfered edges (Figure 6.22). There are 103 of these blocks (90% of all double blocks) with 30-35mm swallows and shell lengths of 215mm to 240mm (Table 6.14a-b). In size, shape, cordage capacity, and style they are almost identical to the first sub-type of single blocks. The only notable differences are that the double blocks have an extra sheave widening them to 140-150mm and, unlike the mix of oak and ash seen in the *sub-type 1* single blocks, almost all of these double blocks are made of oak. There are only four examples made in ash.

Three of those carved from ash (Fnrs 18906, 11430, & 15255) are essentially identical to the oak examples. The fourth (Fnr 08651), however, is somewhat larger at 282mm and is made with a squared out strop score for a 29mm iron strop. The most interesting aspect of this block is not its design, but rather the fact that it has the most pronounced evidence of wear seen on any block in the *Vasa* collection. Its wooden axle pin—37mm in diameter—is heavily worn by the rotation of the sheaves. One sheave cut twice as deep into the axle as the other, indicating that the block was rigged in a purchase tackle which, as expected, had one sheave rotating at twice the rate of the other, thereby causing the difference in wear.

One other outlier in the first sub-type is a comparatively small, oak double block with a narrow 25mm sheave mortise (Fnr 12440). This is far smaller than the other double blocks and does not have an extant partner anywhere in the collection.

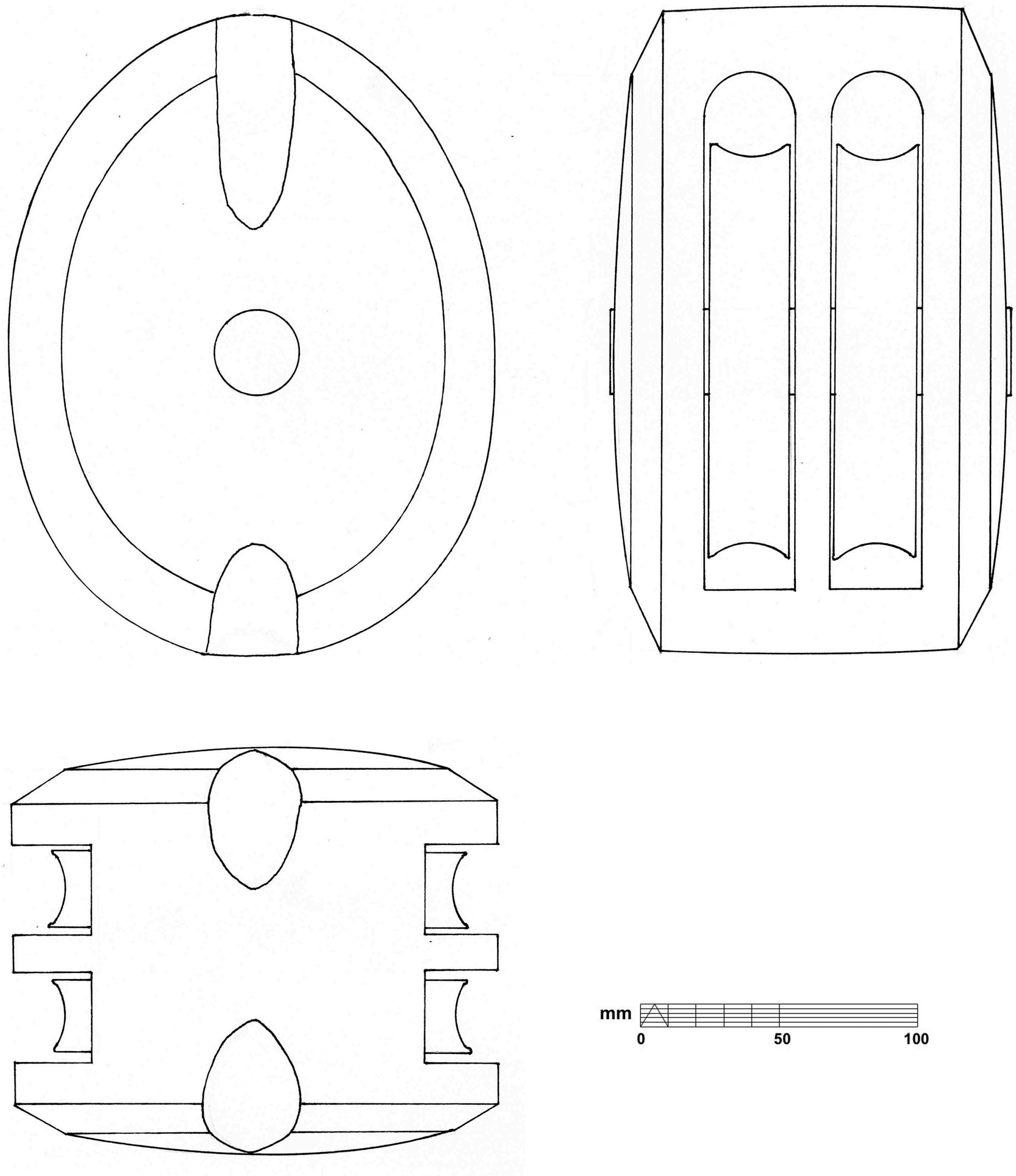


FIGURE 6.22. A *sub-type 1* double block (Drawing by Nathaniel Howe, 2011).

Sub-Type 1 Double Blocks

ID	Shell							1st Sheave			2nd Sheave			Axle	
Find Number	Swallow Dia. (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
12440	25	oak	172	103	98	eroded	unkwn	100	23	ash	99	24	ash	101	23
13713	28	oak	201	133	102	eroded	unkwn	114	28	ash	missing	missing	missing	missing	missing
04178	28	oak	202	127	116	eroded	unkwn	117	22	ash	115	23	ash	119	26
15377	29	oak	197	123	113	14	24	113	25	ash	112	27	ash	116	23
15253	29	oak	201	141	112	eroded	27	130	26	ash	129	27	ash	118	25
NN10	30	oak	202	126	116	15	23	119	26	ash	119	24	ash	117	21
04155	30	oak	212	138	119	eroded	30	119	25	ash	119	25	ash	127	26
07586	30	oak	215	140	120	19	27	127	26	ash	127	24	ash	125	29
11134	30	oak	215	141	115	eroded	27	122	27	ash	130	26	ash	122	27
00416	30	oak	233	145	131	eroded	25	140	27	ash	140	26	ash	134	24
15724	31	oak	190	121	106	eroded	unkwn	105	26	ash	104	26	ash	112	23
12525	31	oak	199	132	120	eroded	29	121	27	ash	123	29	ash	126	27
13744	31	oak	199	125	120	eroded	23	122	24	ash	122	26	ash	122	25
NN11	31	oak	205	135	113	eroded	28	125	24	ash	125	25	ash	119	25
08653	31	oak	208	135	113	eroded	24	116	26	ash	118	26	ash	119	24
11551	31	oak	213	130	121	eroded	24	121	28	ash	117	28	ash	110	25
08689	31	oak	215	137	118	19	28	122	27	ash	125	26	ash	126	26
07701	31	oak	217	138	128	eroded	24	135	28	ash	139	28	ash	131	27
07703	31	oak	219	130	117	eroded	28	128	27	ash	117	26	ash	unknwn	27
13396	31	oak	222	147	117	20	29	138	28	ash	142	28	ash	125	27
08193	31	oak	240	165	127	16	29	157	27	ash	157	29	ash	129	30
09198	31	oak	245	170	115	21	27	151	33	ash	151	32	ash	137	28
11171	32	oak	194	124	121	eroded	26	124	27	ash	123	26	ash	123	28
09638	32	oak	199	125	123	eroded	26	118	25	ash	118	28	ash	125	26
15252	32	oak	199	141	118	16	31	missing	missing	missing	missing	missing	missing	121	24
11135	32	oak	202	123	122	16	23	112	25	ash	117	24	ash	125	27
13887	32	oak	204	126	120	15	24	122	25	ash	123	24	ash	114	26
15376	32	oak	210	137	120	16	29	129	27	ash	129	27	ash	116	26
24237	32	oak	210	130	111	15	28	126	30	ash	128	27	ash	118	28
08451	32	oak	211	143	125	15	24	136	28	ash	140	27	ash	122	27
05029	32	oak	213	144	120	19	27	139	27	ash	132	26	ash	128	28
12590	32	oak	213	135	115	18	22	123	27	ash	120	26	ash	121	26
03848	32	oak	215	127	124	17	24	127	27	ash	133	26	ash	131	30
14017	32	oak	216	134	121	eroded	27	129	26	ash	128	28	ash	115	26
11624	32	oak	222	141	125	eroded	25	130	27	ash	138	26	ash	131	27
12323	32	oak	222	130	118	eroded	24	132	27	ash	132	26	ash	125	29
14098	32	oak	223	147	126	21	29	134	26	ash	136	27	ash	129	27
11404	32	oak	225	156	124	eroded	24	141	27	ash	142	27	ash	127	25
03301	32	oak	227	149	136	eroded	36	139	27	ash	135	28	ash	135	27
11474	32	oak	227	149	126	18	28	142	27	ash	144	39	ash	128	26
03912	32	oak	238	158	135	17	29	149	29	ash	147	30	ash	142	26
07658	32	oak	239	143	130	14	28	139	28	ash	142	39	ash	133	26
11190	32	oak	241	155	129	18	26	149	28	ash	148	28	ash	132	27
10577	32	oak	245	150	136	18	27	153	29	ash	148	27	ash	138	27
10600	33	oak	191	120	126	20	24	108	20	ash	109	27	ash	123	27
13375	33	oak	208	128	120	eroded	24	122	24	ash	122	23	ash	125	22
10586	33	oak	210	134	116	eroded	24	131	27	ash	123	25	ash	121	26

TABLE 6.14a. List of *sub-type 1* double blocks organized by swallow size (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-Type 1 Double Blocks (*continued*)

ID	Shell							1st Sheave			2nd Sheave			Axle	
Find Number	Swallow Dia. (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
12545	33	oak	215	132	118	15	30	123	27	ash	123	26	ash	121	27
04024	33	oak	216	149	124	14	30	139	26	ash	135	26	ash	127	27
11341	33	oak	218	135	129	eroded	26	133	29	ash	139	30	ash	130	27
09901	33	oak	220	148	116	16	unkwn	137	25	ash	137	28	ash	123	27
07588	33	oak	222	143	124	18	25	128	26	ash	130	27	ash	125	26
09550	33	oak	222	146	128	16	23	134	28	ash	132	27	ash	130	27
08456	33	oak	223	146	118	19	26	137	28	ash	137	27	ash	123	26
11107	33	oak	223	150	124	20	28	138	27	ash	134	27	ash	130	26
11305	33	oak	226	150	121	17	28	140	26	ash	140	29	ash	124	26
10813	33	oak	227	147	128	18	24	136	129	ash	139	30	ash	133	28
03528	33	oak	228	149	125	18	30	128	28	ash	133	27	ash	missing	missing
03987	33	oak	228	144	121	16	24	137	26	ash	136	26	ash	127	27
10883	33	oak	228	144	127	20	27	135	28	ash	135	27	ash	134	27
13729	33	oak	231	153	132	20	28	133	28	ash	132	28	ash	127	28
03757	33	oak	233	153	132	19	27	147	27	ash	141	27	ash	137	26
09769	33	oak	237	152	133	18	unkwn	143	31	ash	143	26	ash	139	27
11596	33	oak	242	157	134	22	26	145	27	ash	147	28	ash	136	27
08192	33	oak	243	151	120	23	28	134	26	ash	133	28	ash	133	26
03790	33	oak	245	152	124	eroded	28	143	27	ash	143	27	ash	133	29
09902	34	oak	204	135	115	18	24	122	29	ash	121	27	ash	broken	27
12890	34	oak	213	136	118	eroded	unkwn	128	21	ash	128	24	ash	123	28
13392	34	oak	220	151	130	eroded	26	133	27	ash	138	28	ash	129	27
10554	34	oak	221	144	126	20	28	131	27	ash	134	28	ash	126	27
03529	34	oak	222	148	125	15	23	137	28	ash	133	29	ash	129	27
11056	34	oak	222	141	127	18	26	136	26	ash	134	27	ash	131	27
11468	34	oak	222	148	121	eroded	unkwn	135	26	ash	135	24	ash	128	27
07755	34	oak	228	152	136	19	24	137	29	ash	131	28	ash	140	27
10551	34	oak	230	156	131	20	27	141	27	ash	144	28	ash	134	26
10719	34	oak	232	148	120	18	28	134	28	ash	134	25	ash	124	27
20794	34	oak	232	143	141	20	28	134	29	ash	134	28	ash	144	27
17026	34	oak	233	147	129	17	29	140	28	ash	141	28	ash	127	27
09972	34	oak	236	155	129	eroded	28	147	27	ash	144	27	ash	missing	missing
14610	34	oak	236	149	129	19	28	127	27	ash	139	26	ash	125	26
04124	34	oak	238	159	123	18	unkwn	148	25	ash	142	26	ash	126	29
05087	34	oak	239	152	127	eroded	25	145	26	ash	146	27	ash	140	26
18906	34	ash	240	148	134	20	28	151	30	ash	152	29	ash	140	27
11430	35	ash	210	120	110	eroded	21	missing	missing	missing	missing	missing	missing	missing	missing
12322	35	oak	214	145	120	eroded	25	132	27	ash	132	26	ash	missing	missing
12479	35	oak	217	139	123	eroded	24	132	27	ash	129	26	ash	127	27
08463	35	oak	236	158	133	18	28	150	29	ash	141	27	ash	134	27
03460	35	oak	240	152	125	17	27	150	28	ash	153	26	ash	132	26
15713	35	oak	240	180	127	13	30	155	30	ash	155	31	ash	127	26
11169	35	oak	241	159	129	19	29	145	27	ash	145	28	ash	133	26
03666	35	oak	247	160	135	18	27	152	32	ash	151	31	ash	140	27
15257	36	oak	204	128	112	14	24	128	31	ash	126	31	oak	116	26
09350	36	oak	235	153	118	eroded	unkwn	147	30	ash	142	26	ash	128	28
13746	36	oak	240	151	127	18	27	151	28	ash	155	27	ash	130	27
19362	36	oak	244	154	133	21	29	143	29	ash	150	30	ash	141	27
20452	37	oak	222	135	130	eroded	24	136	28	ash	139	28	ash	missing	missing
10180	37	oak	239	155	134	16	29	146	28	ash	146	29	ash	137	28
07890	38	oak	210	130	116	eroded	unkwn	128	23	ash	126	29	ash	124	28
15255	39	ash	230	156	130	16	31	145	30	ash	149	32	ash	136	24
11197	unkwn	oak	212	122	xx	eroded	26	100	26	ash	92	23	ash	broken	23
10079	unkwn	oak	214	126	112	eroded	30	116	19	ash	117	21	ash	broken	27
05074	unkwn	oak	229	147	119	21	29	137	27	ash	126	27	ash	126	27
08651	34	ash	282	177	153	21	29	174	31	ash	173	31	ash	147	37

TABLE 6.14b. List of *sub-type 1* double blocks organized by swallow size and strop type. The last block in the list was fitted with an iron hook strop (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 2. Elliptical with rounded edges and broad strop scores. A variant of the first sub-type design is a massive 481mm-long block (Fnr 12885) with smooth rounded edges, very broad 85mm strop scores, and 48mm swallows (Table 6.15). Its two 300mm sheaves are of equal size and are arranged side-by-side (Figure 6.23). This block is very similar in style to a treble block found nearby (Fnr 12884).

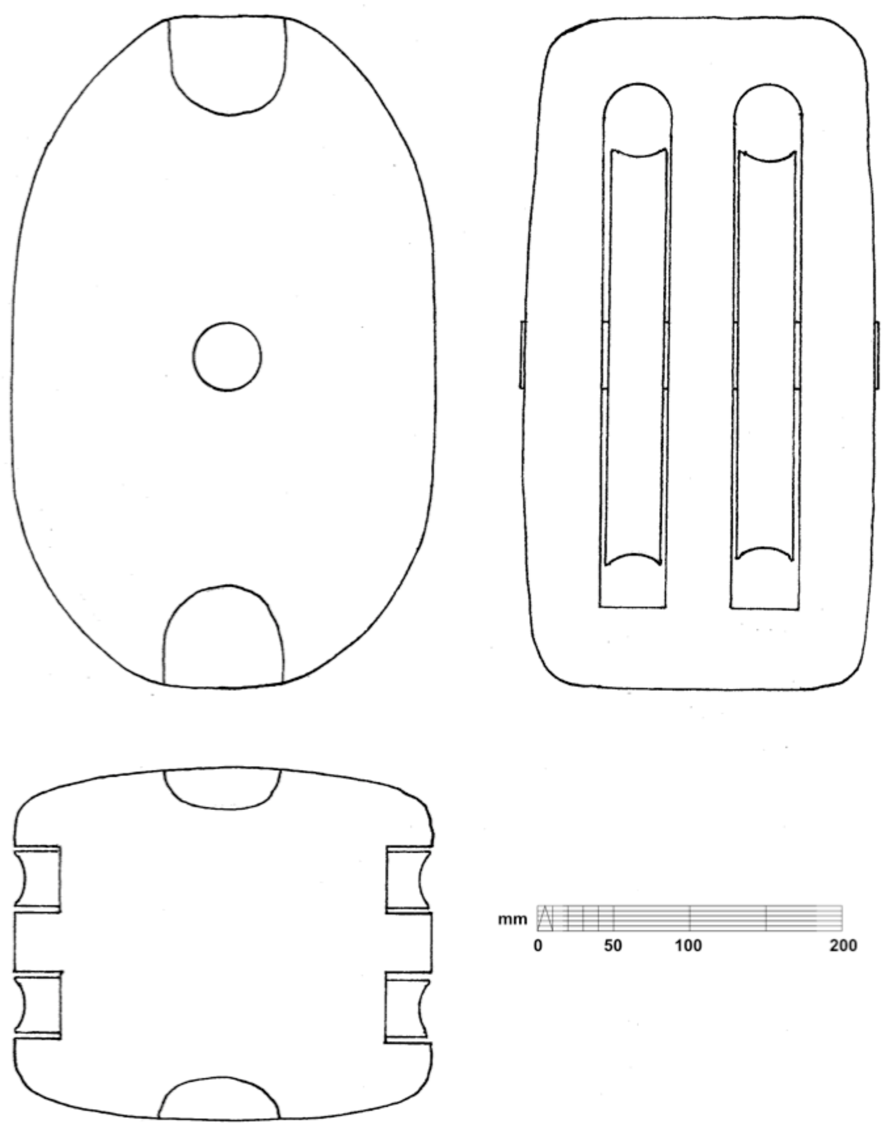


FIGURE 6.23. A *sub-type 2* double block (Drawing by Nathaniel Howe, 2011).

Sub-Type 2 Double Block

ID	Shell						Sheaves			Axle	
Find Number	Swallow Diameter (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Diameter (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
12885	48	oak	481	270	256	85	297	43	ash	245	52

TABLE 6.15. Essential data for the *sub-type 2* double block (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 3. Fiddle Blocks. The second largest group of double blocks have elongated, figure-of-eight shaped shells containing two sheaves of different sizes arranged end-to-end in the same plane (Figure 6.24). These are easily recognizable as fiddle blocks. For four of the five examples, the two sheaves are the same thickness, indicating that these carried the same size cordage and were used in rigging what are known as long tackles—a name reflecting the elongated blocks that streamline the profile of the tackle. The fifth fiddle block may have had the same dimensions as well, but it could not be located for study (Table 6.16).

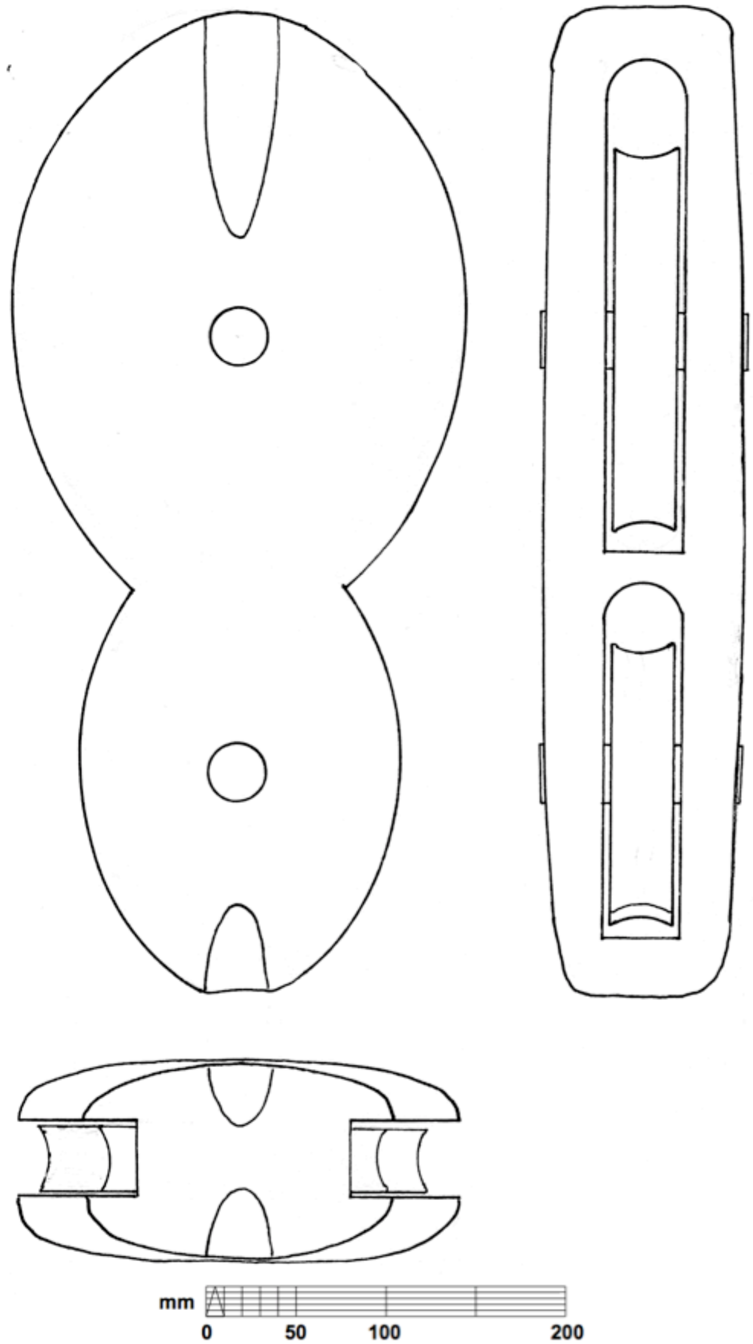


FIGURE 6.24. A *sub-type 3* double block, a fiddle block (Drawing by Nathaniel Howe, 2011).

Sub-Type 3 Double Block

ID	Shell						1st sheave			1st axle		2nd sheave			2nd axle	
Find Number	Swallow Dia. No.1/No.2 (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
23140	34/34	ash	447	202	110	38	169	30	ash	78	32	123	29	ash	98	29
20795	40/37	ash	456	254	93	37	175	24	ash	99	28	126	29	ash	96	28
19365	52/42	oak	679	257	112	49	264	33	ash	122	43	204	30	ash	114	37
23885	57/47	oak	697	253	130	43	240	43	ash	137	41	197	43	ash	136	37
18775	unknown	x	x	x	x	x	x	x	ash	x	x	x	x	ash	x	x

TABLE 6.16. List of *sub-type 3* double blocks organized by swallow size of the larger sheave (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 4. Long Tackle Pendant Blocks. The fourth double block sub-type is, in function and arrangement of the sheaves, the same as a fiddle block. Yet, these four blocks are notably different in form, lacking the figure-of-eight fiddle shape and being much more elongated (Figure 6.25). More significantly, these blocks were not stropped. Instead, these blocks have a large eyehole bored through the head for a pendant. The four blocks of this sub-type all have the same size swallows, averaging 32mm. This is true of both sheaves even though they differ in diameter. The shell lengths are more variable, ranging from 588mm to 654mm while the eyehole is consistently about 50-55mm in diameter (Table 6.17).

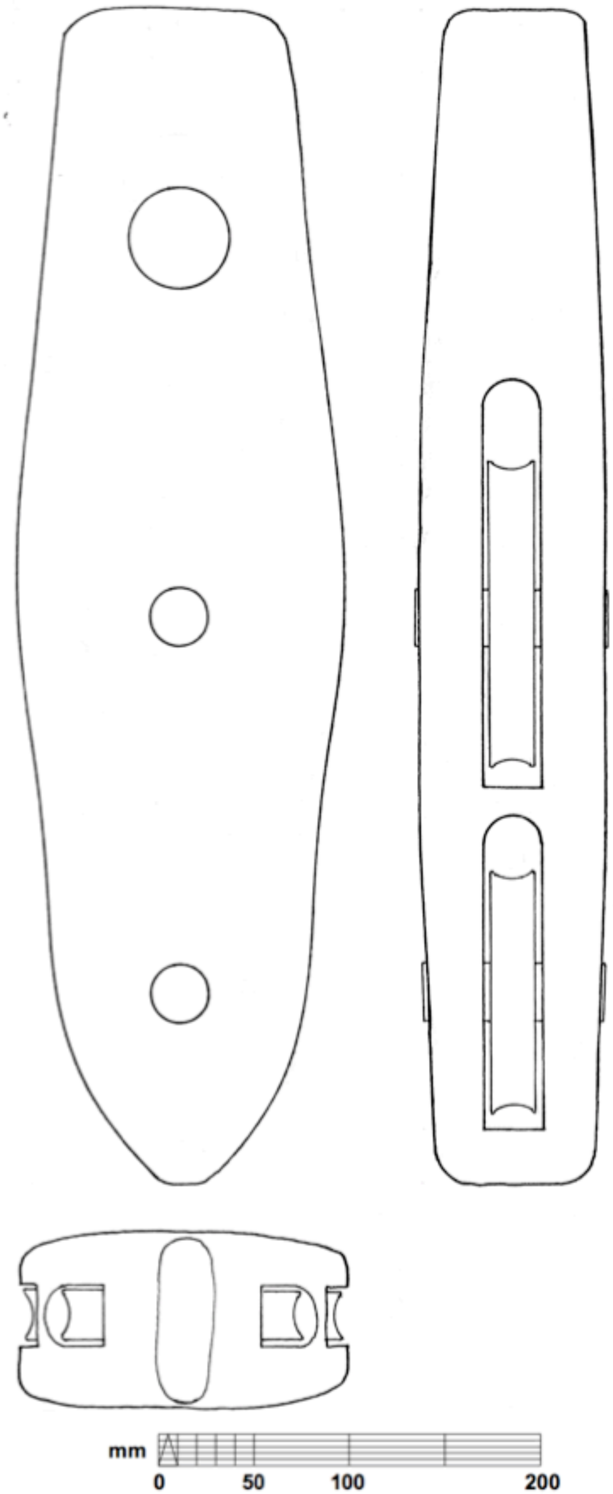


FIGURE 6.25. A *sub-type 4* double block, a non-stropped long tackle block (Drawing by Nathaniel Howe, 2011).

Sub-Type 4 Double Block

ID	Shell						1st sheave			1st axle		2nd sheave			2nd axle	
Find Number	Swallow Dia. No.1/No.2 (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Pendant size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
18904	31/32	ash	637	172	89	59	159	31	ash	102	30	116	29	ash	100	29
18908	32/32	ash	588	165	90	54	154	31	ash	90	28	119	25	ash	84	29
18982	32/32	ash	602	171	91	53	167	29	ash	93	29	127	28	ash	93	26
19234	35/32	ash	654	158	93	58	152	30	ash	97	27	NA	NA	NA	NA	NA

TABLE 6.17. List of *sub-type 4* double blocks organized by swallow size of the larger sheave (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 5. Double–Sheaved Pendant Block. There is a lone double-sheaved pendant block in the *Vasa* collection (Fnr 20244) (Figure 6.26). It has a piriform shell with two equal sized sheaves set side-by-side in the lower, broader portion of the shell. It is made to handle cordage up to 36mm in diameter and has a shell length of 417mm. The eyehole, which is tapered toward the head to seat the eye splice securing the block, is 47mm in diameter (Table 6.18). In form, it is essentially a crane block.

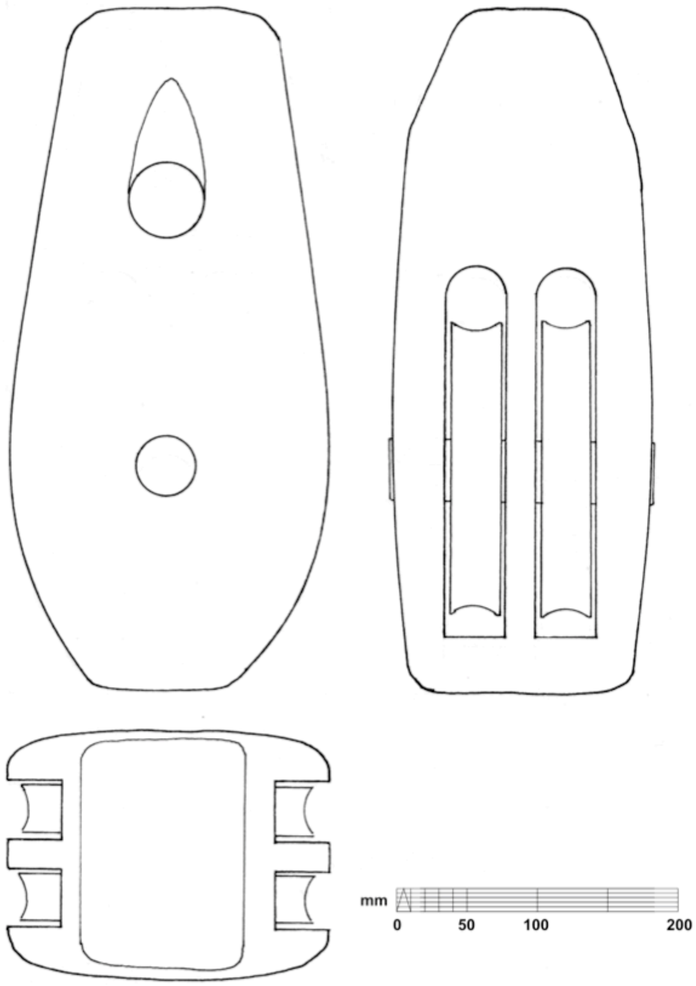


FIGURE 6.26. The *sub-type 5* double-sheaved pendant block (Drawing by Nathaniel Howe, 2011).

Sub-Type 5 Double Block

ID	Shell						1st sheave			2nd sheave			Axle	
Find Number	Swallow Dia. No.1/No.2 (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Pendant hole dia. (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)
20244	36/36	ash	417	196	155	47	177	27	ash	175	26	ash	167	37

TABLE 6.18. Diagnostic data for the *sub-type 5* double block (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Sub-type 6. Combined-Topsail-Sheet-and-Lift Block. The most complex double block associated with *Vasa* is a large pear-shaped block containing two sheaves of different sizes that are set end-to-end, but pivoted 90° to one another along the block's longitudinal axis (Figure 6.27). Although unusually bulky, this block is easily recognizable as a Dutch-style combined topsail sheet and lift block. Only one of these blocks was recovered with *Vasa* (Fnr 23455), measuring 715mm long. The larger of its two sheaves measures 370mm in diameter and 77mm thick, while the smaller sheave is 170mm in diameter and 38mm thick (Table 6.19).

Perhaps the most unusual aspect of a Dutch-style combined topsail-sheet and lift block like the one found with *Vasa* is that the strop passes through the middle of the block at the lower end of the smaller sheave mortise and thus only offers support to the broader portion of the block that carries the topsail-sheet. This stropping configuration is necessary to avoid fouling one of the sheaves, but it also illustrates the disparity between the forces being exerted on the two sheaves, the lift having relatively little strain on it for leveling the yard while the topsail-sheet must resist the pressure of the wind in the expansive topsail.

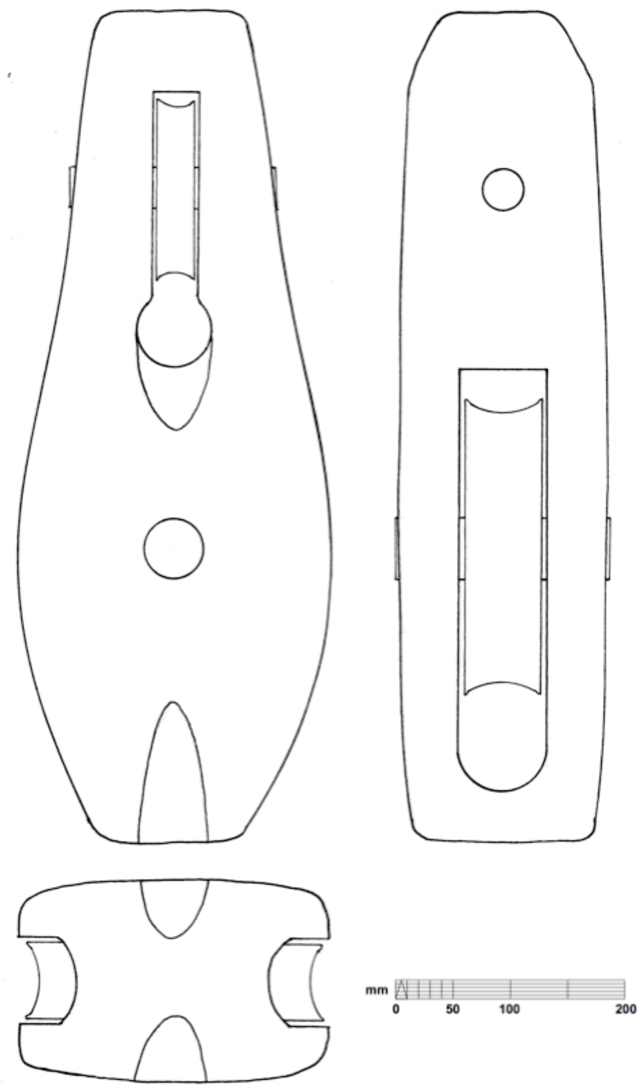


FIGURE 6.27. *Sub-type 6* double block, a Dutch combined topsail sheet and lift block (Drawing by Nathaniel Howe, 2011).

Sub-Type 6 Double Block

ID	Shell						1st sheave			1st axle		2nd sheave	2nd axle
Find Number	Swallow Dia. No.1/No.2 (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood species	Length (mm)	Dia. (mm)		
23455	77/38	ash	715	271	179	62	254	63	ash	186	53	missing	missing

TABLE 6.19. Diagnostic data for the *sub-type 6* double block found with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Triple Sheaved Blocks

The *Vasa* block collection contains only two triple-sheaved blocks. Both blocks have sheaves of a uniform size, all arranged side-by-side on a single axle. The first block (Fnr 12884) is a bulbous 483mm block with smooth rounded edges and unusually broad 96mm strop scores (Figure 6.28). Its swallows can carry cordage up to 55mm in diameter over the large 363mm ash sheaves (Table 6.20). This block features very clear 15mm-wide chisel marks in the strop score.

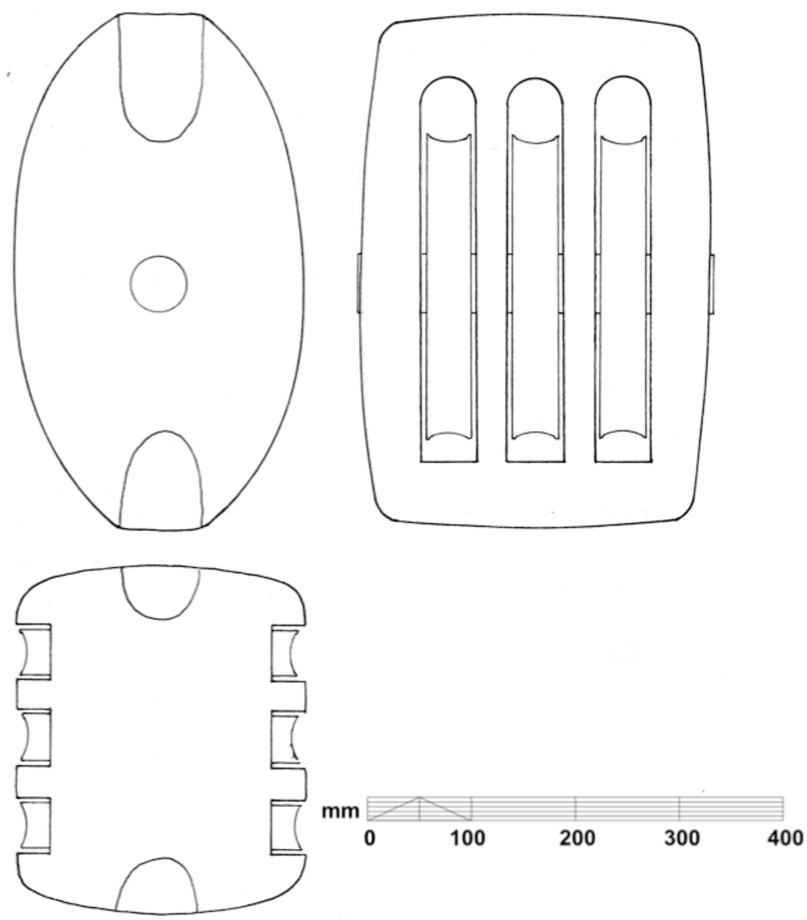


FIGURE 6.28. The first of the two triple-sheaved blocks from *Vasa*, Find Number 12884 (Drawing by Nathaniel Howe, 2011).

Sub-Type 1 Treble Block

ID	Shell						1st sheave			2nd sheave			3rd sheave			Axle	
Find Number	Swallow Dia. (mm)	Wood spec.	Length (mm)	Width (mm)	Thick-ness (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Wood spec.	Dia. (mm)	Thick-ness (mm)	Wood spec.	Dia. (mm)	Thick-ness (mm)	Wood spec.	Length (mm)	Dia. (mm)
12884	55	oak	483	270	330	96	284	44	ash	286	45	ash	295	45	ash	334	55

TABLE 6.20. Data for the lone *sub-type 1* treble block found with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

The second triple block (Fnr 10923) is a very large 485mm-long treble with chamfered edges, 73mm swallows, 295mm-diameter iron sheaves, and a bulky extrusion off the head of the block that gives it a pear-shape when viewed from the side (Figure 6.29). A 90mm eyehole for securing a pendant is bored through this extrusion, perpendicular to the plane of the sheaves (Table 6.21). The hole is tapered toward the head at both ends to ease the bend of the pendant (or tye). This block is identical to a traditional Dutch ram's head block of the period for ships with the tyes rigged over the mast cap, thus not requiring a fourth sheave (Hoving 2000:72-73). Yet, as will be explored in detail later in this thesis, this was certainly not one of *Vasa's* ram's head blocks.

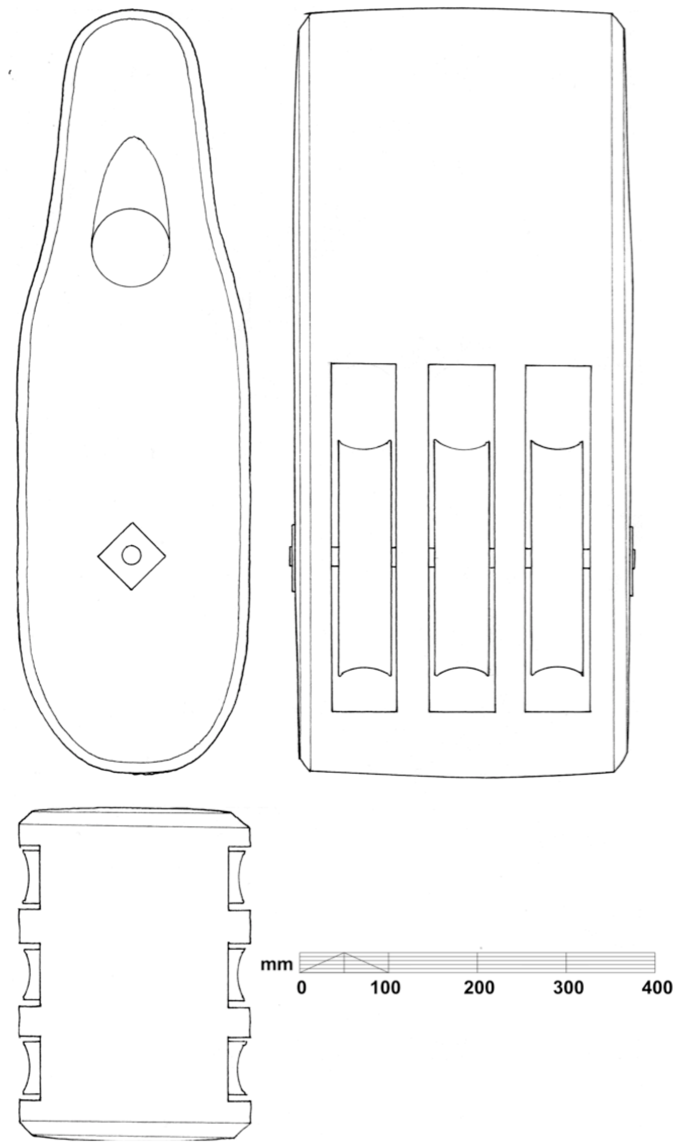


FIGURE 6.29. The large *sub-type 2* treble block carrying iron sheaves (Drawing by Nathaniel Howe, 2011).

Sub-Type 2 Treble Block

ID	Shell							All 3 sheaves			Axle	
Find Number	Swallow Dia. (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)	Dia. (mm)	Thick-ness (mm)	Material	Length (mm)	Dia. (mm)
10923	73	ash	875	383	264	20	90	295	65	iron	NA	NA

TABLE 6.21. Data for the lone *sub-type 2* treble block found with *Vasa* (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

Quadruple Sheaved Blocks

The most complex blocks recovered with *Vasa* is a pair of blocks each carrying four sheaves. Both are pear-shaped with chamfered edges. Three of the sheaves are the same size and are arranged side-by-side on a single axle in the broader portion of the pear shape. The smaller—but thicker—fourth sheave is set in the narrower portion of the shell, end-to-end with the other sheaves, but rotated 90° on the block's longitudinal axis so that its sheave mortise crosses the ends of those below it (Figure 6.30).

Both of these blocks are readily recognizable as ram's head blocks, the type employed aboard virtually all large ships of the era for raising the enormous course yards loaded with several tons of blocks, lines, and sailcloth. Ram's head blocks for ships with a single tye in the halyard system had only three sheaves, being essentially identical to one of the triple blocks found on *Vasa* (Marquardt 1986:76; Hoving 2000:72-73). Larger ships with two tyes supporting the yard, however, often had an additional sheave in the ram's head block to allow the tyes to shift when the yard was braced around.

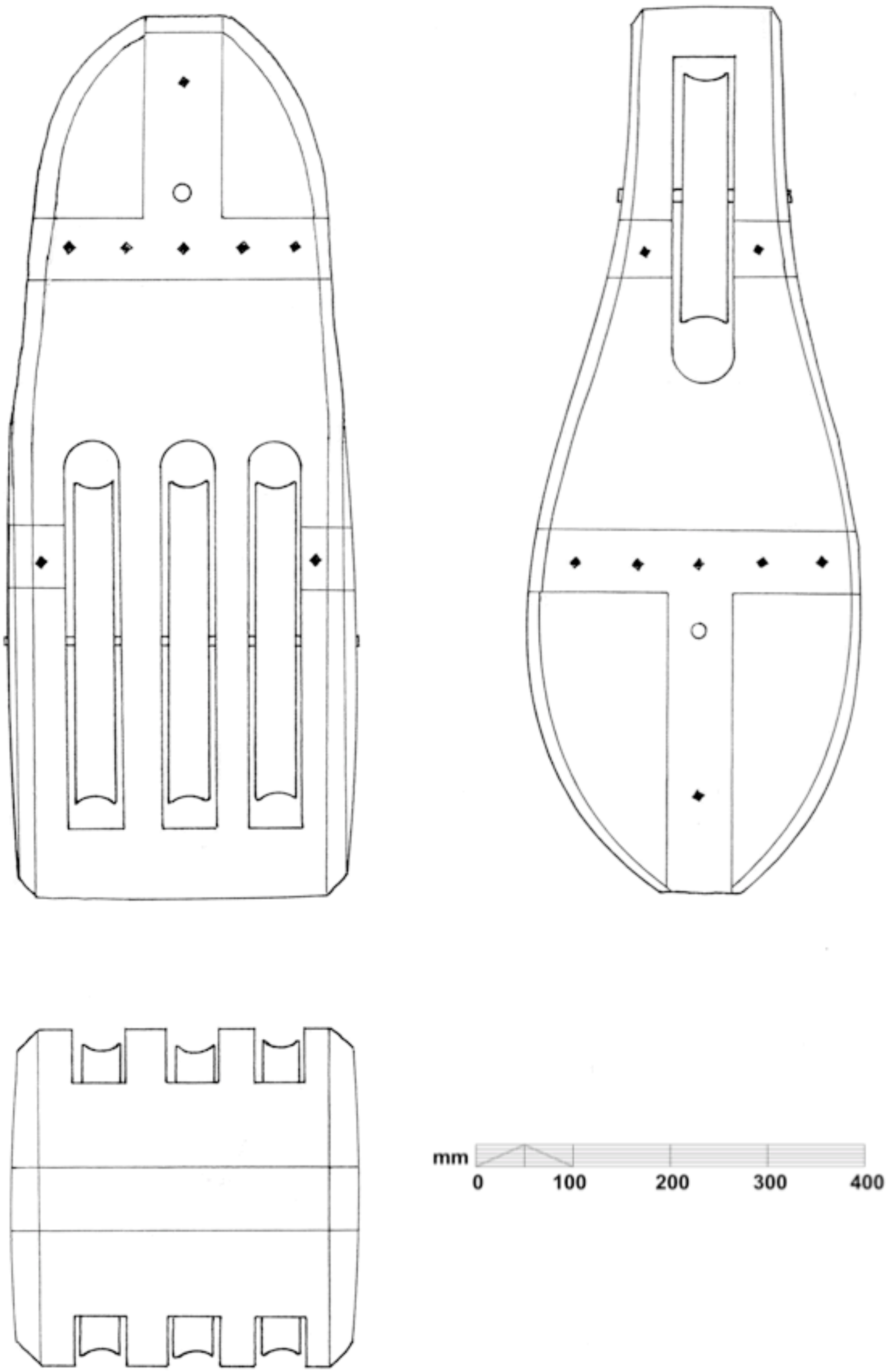


FIGURE 6.30. Ramshead block from *Vasa* (Drawing by Nathaniel Howe, 2011).

Quadruple Blocks

ID	Shell						
Find Number	Swallow Dia. No.1/No. 2 (mm)	Wood species	Length (mm)	Width (mm)	Thick-ness (mm)	Chamfer width (mm)	Strop size (mm)
09843	80/50	ash	1015	360	377	35	80
08008	80/60	oak	962	345	375	32	NA

ID	Sheaves 1 - 3			Sheave 4			1st Axle		2nd axle	
Block Find Number	Dia. (mm)	Thick-ness (mm)	Material	Dia. (mm)	Thick-ness (mm)	Material	Dia. (mm)	Mater ial	Dia. (mm)	Material
09843	400	60	iron	280	59	iron	44	iron	40	iron
08008	NA	NA	iron	NA	NA	NA	52	iron	46	iron

TABLE 6.22. Data on *Vasa*'s two quadruple-sheaved blocks (Data gathered from *Vasa* blocks collection; table by Howe, 2011).

The largest of *Vasa's* two ram's head blocks (Fnr 09843) is 1015mm in length and weighs in at 64.5 kg without its heavy cast-iron sheaves and iron strapping (Table 6.22). It is cut from a solid block of ash and, given its breadth across the grain (more than 360mm), required an entire trunk section of a tree to produce. The heartwood runs almost straight up through the middle of the block. The edges of the shell are chamfered and the iron belts and stropping bands that guard against splitting can still be seen as a series of small nail holes and faint 'ghosts,' or ridges, left in the wood. These strops could not go around the entire block without obstructing the sheave mortises of the perpendicular sheave(s). Thus an 80mm-wide iron strop was passed around each end extending up the cheeks to a point just beyond the nearest axle butt where they stop to form a 'T' with a

35mm-wide iron belt wrapping around the cheeks as far as the sheave mortise. These strops were nailed to the block cheeks approximately every 60mm.

All four sheaves seated in this block were cast-iron. These have been removed for conservation and are being examined as part of current *Vasa* ironwork research. The sheave mortises for the three lower sheaves are each 455mm long and 50mm wide. The fourth sheave mortise in the narrower portion of the block is of considerably stouter dimensions, measuring in at only 368mm long but 80mm wide—an indicator of the thickness of the heavy tye ropes.

The second and slightly smaller ram's head block (Fnr 08008) is identical in form and detailing, but shorter by about 50mm and, most strikingly, is made of oak rather than ash. The fact that the two ram's head blocks—the largest and most heavily stressed blocks in the entire rig—are made from different wood species suggests that the builders had little preference for one species over another. Another intriguing aspect is that this block features distinct circular wear patterns in the sheave mortises. These appear in the three parallel sheave mortises and grow progressively deeper from one mortise to the next. This would be expected in a multi-sheave tackle block where the sheave nearest the working end of the fall would be rotating several times faster than the sheave closest to the standing end. This may indicate loose-fitting sheaves or considerable use, perhaps even before the block was rigged on *Vasa*.

Block Fragments

In addition to the 412 extant blocks there were 143 fragments of shells, sheaves, axle pins, or combinations thereof. Due to the severity of the damage to these artifacts, it is not clear how many individual blocks these 143 fragments represent. Many were too decayed by surface erosion to even assign to one of the aforementioned groups, although the vast majority of these lumps and fragments were at least recognizable as fragments of oak or ash blocks consistent with the known types. The only exceptions were the cheeked sheaves and those made of *lignum vitae* (types 2 and 3) as well as a block provisionally tagged NN38 that appears to have had an iron bearing set into the walls of the sheave mortise.

Chapter 7. Distribution

Find Locations

Blocks were recovered from all five of *Vasa's* full-length decks as well as from the mud around the ship (Figure 7.1). On the gundecks, the blocks were fairly evenly distributed. In other parts of the site they were heavily concentrated in specific areas. This was particularly true in the hold and on the orlop. Although the size and form of a particular block provides important clues as to its original place and function in the rig, distribution and find location are the most critical evidence for developing an accurate reconstruction. This chapter examines the find locations by deck or general find area. The exact find location of each block and fragment is presented in tabular form in the appendix (Tables Appendix.1-7).

FIGURE 7.1. An unidentified block recovered from *Vasa* still fitted with its hempen strop (Courtesy of the Vasa Museum).

Weather Deck

Fewer blocks were recovered from the weather deck than any other major find location. Although the weather deck is directly below the rig and is therefore the most logical place for collapsing elements of the rig to come to rest, the aggressive salvage operations of Treileben and Peckell in the 1660s virtually destroyed it (Cederlund 2006:84). In their efforts to remove the ship's valuable bronze cannon, they forcibly tore away the entire deck. Any blocks that had settled there were cast overboard, knocked down to the upper gundeck, or hauled away with the discarded decking. The sparse remnants of the weather deck that remained caught only four pieces of rigging hardware—a block, a deadeye, one euphroe, a sheave, and a fragment of another sheave.

The lone block is an ash pendant block (Fnr 03016) recovered from the foremost part of the deck. It has some moderate erosion, but is otherwise in remarkably good condition considering its years of exposure to the currents. Beside it lay a *lignum-vitae* sheave (Fnr 03049) from another block. The find location details for the euphroe (Fnr 11068) and the sheave fragment are incomplete, specifying only that those items were on the weather deck.

The Upper Gundeck

The largest concentration of blocks was found on the upper gundeck. That find area alone contained 112 blocks and 44 fragments (Figures 7.2, 7.3, and 7.4). Given the centuries of disruption from currents, salvors, and anchors, it is difficult to estimate what percentage of the blocks found on the upper gundeck among the broken hatch gratings and toppled gun carriages had actually originated there. The removal of the overhead weather deck and the presence of obvious rigging blocks suggest that at least some of those found on the upper gundeck had tumbled down from above.

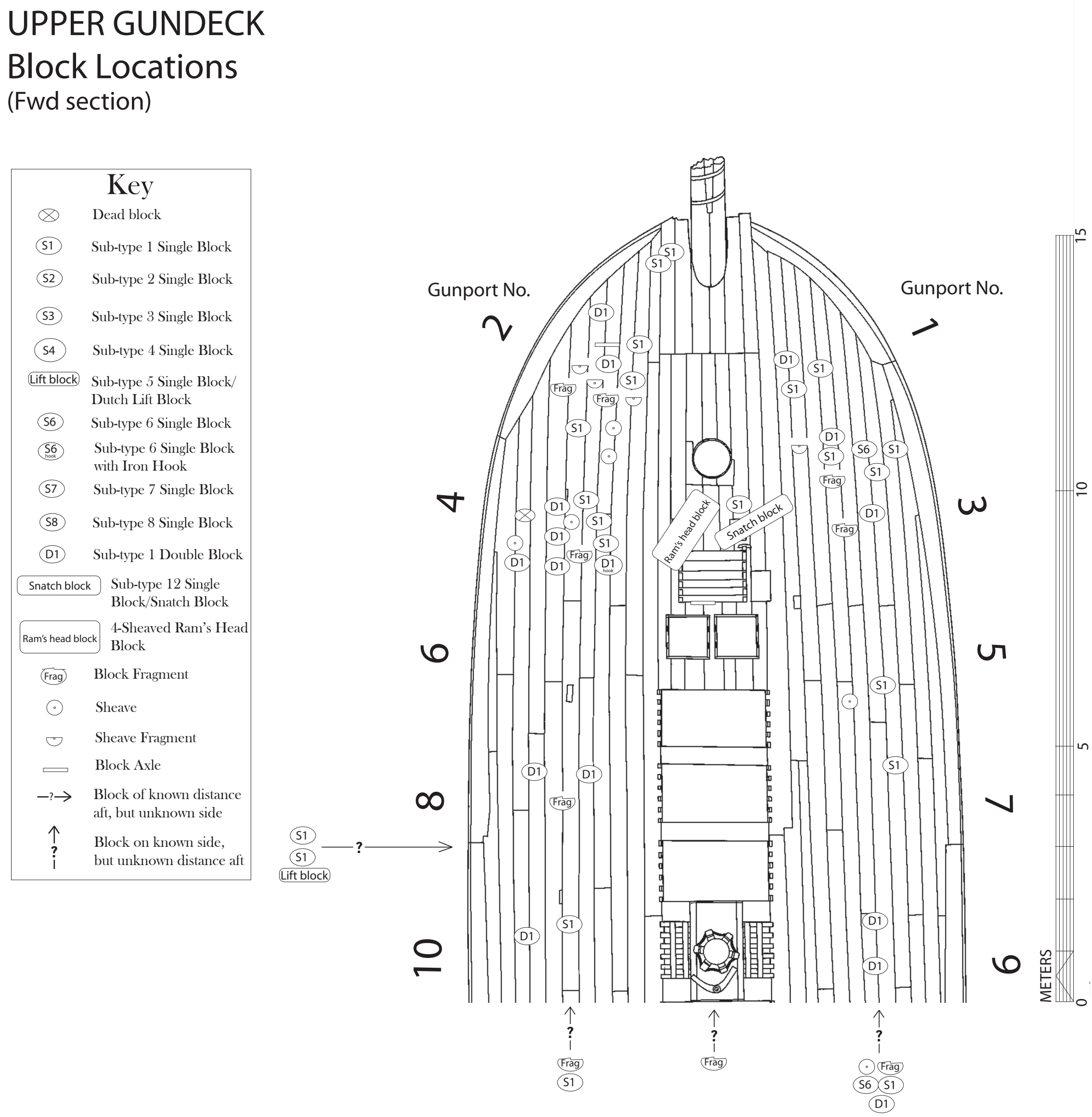


FIGURE 7.2. Distribution of blocks found on the forward section of the upper gundeck (Illustration by Nathaniel Howe, 2011).

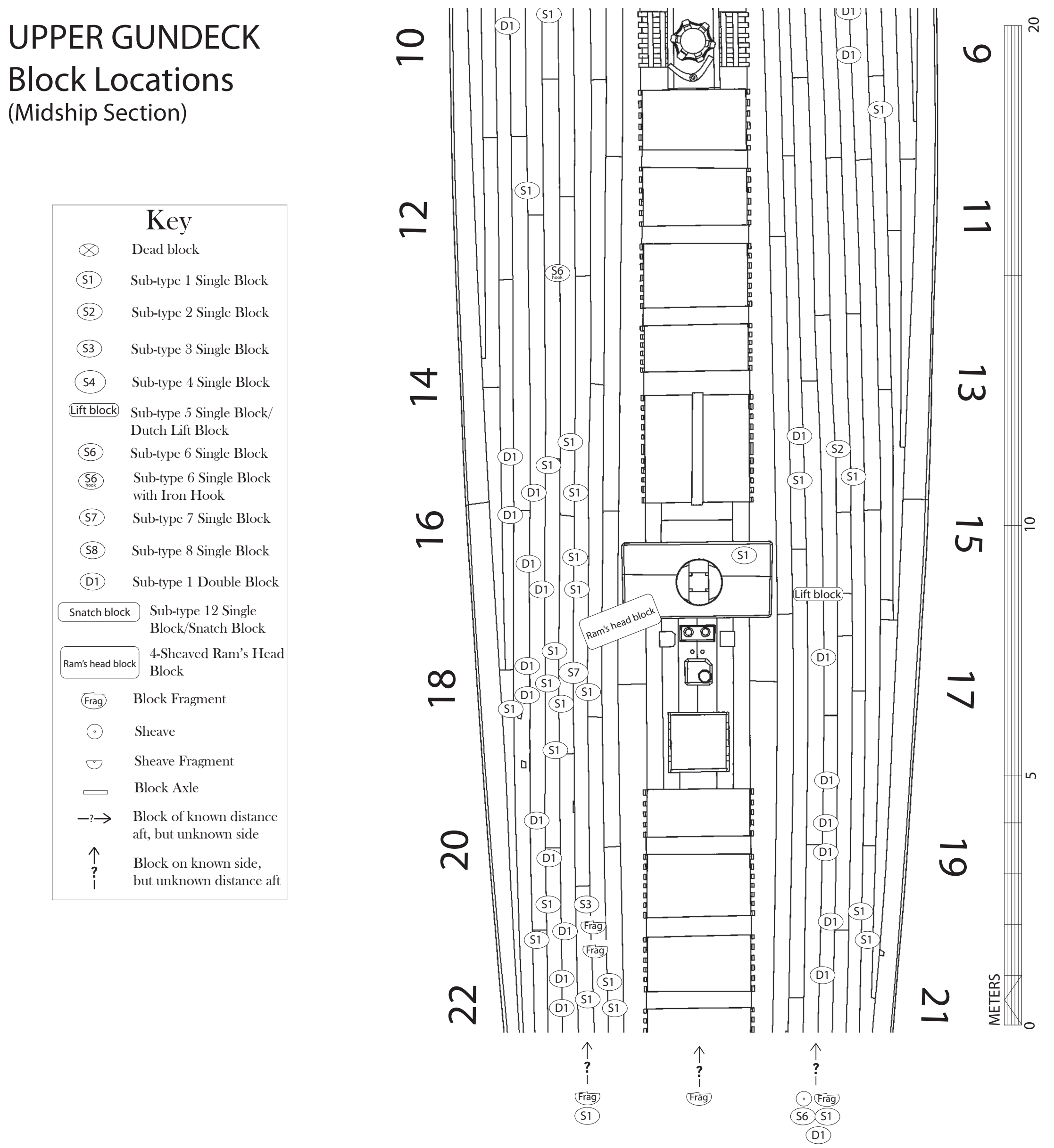


FIGURE 7.3. Find locations for blocks on midship section of the upper gundeck (Illustration by Nathaniel Howe, 2011).

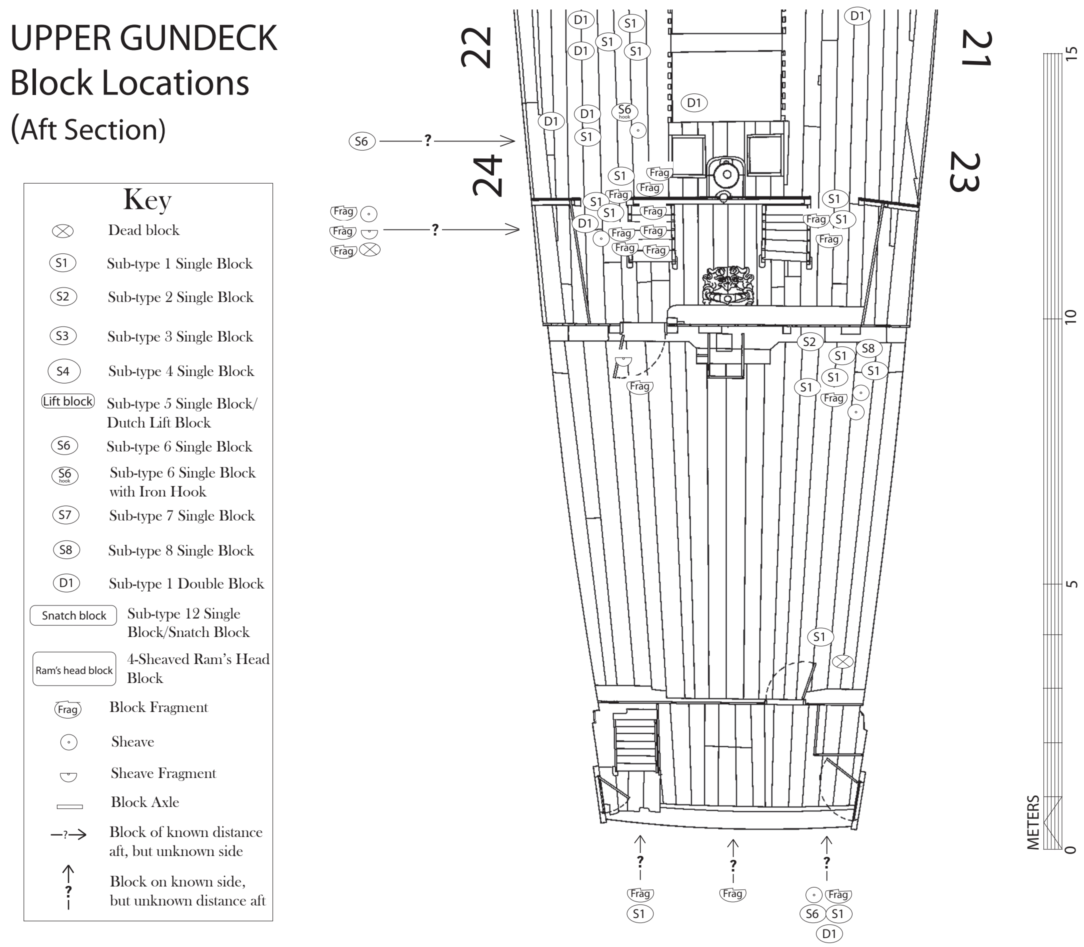


FIGURE 7.4. Find locations for blocks on aft section of the upper gundeck (Illustration by Nathaniel Howe, 2011).

Seven major block types were found on the upper gundeck including single blocks, double blocks, ram's head blocks, dead blocks, upper lift blocks, a snatch block, and several iron-stropped hook blocks. The single and double blocks were scattered relatively evenly throughout the upper gundeck, while the specialized blocks were largely strewn amidships along the port side and fragments mostly appeared on the badly damaged fore and aft portions of the deck.

To discuss the distribution of blocks on the upper gundeck by specific find areas in any greater detail is impractical. There are only four clearly defined areas with solid, physical boundaries on the upper gundeck: the gundeck proper, the steering compartment, the great cabin, and the stern gallery. The distribution of the various block types in these areas is so thoroughly intermixed that any description of the finds by location on the deck is unavoidably confusing, cumbersome, and analytically tenuous. Consequently, the distribution of blocks on the upper gundeck must be organized by block type.

Single blocks were the most common type found on the upper gundeck. In all, 66 examples were scattered more or less evenly throughout the deck. Forty-three of them were made to exactly the same pattern with 30-34mm swallows cut for 25-30mm cordage and had shell lengths averaging 230mm. All of these blocks fall into the *sub-type 1* classification described in chapter 6. These 43 blocks tended to be distributed in the vicinity of the gunports and around the base of the foremast. The other 23 single blocks on the upper gundeck were of several different styles and sizes, most having smooth rounded edges instead of a chamfer. These blocks range a bit more in size and shape, spanning everything from a little 145mm ash block to a chunky 543mm iron-stropped hook block. Forms varied to include several of the flat-ended piriform blocks (*sub-type 2*), some of the flat lenticular blocks (*sub-type 4*), as well as a pair of upper lift blocks (*sub-type 5*).

The double blocks were bulky enough to stand above the slowly accumulating sediment for several decades after *Vasa* sank. Consequently, most of them were severely eroded by abrasive particulates in the current (Figure 7.5). In all, 37 identifiable double blocks were scattered about the upper gundeck. Their distribution roughly mirrors that of the *sub-type 1* single blocks; they were more or less evenly distributed, but appeared in pairs or small clusters near the gunports, particularly aft of the main hatch. All but one of the double blocks are *sub-type 1* double blocks, having elliptical shells with chamfered edges and 30-34mm swallows. Their shells are carved from oak and they are all between 230mm and 240mm in length. The sole exception is an iron-stropped double block found up forward on the port side (Fnr 08651). Unlike most of the iron-stropped blocks found in association with *Vasa*, this one appears to have been made for iron stropping from the start; the strop score shows no evidence of being re-cut from a dished channel for a cordage strop to a squared channel for an iron band.

FIGURE 7.5. A severely eroded double block from the upper gundeck (Photo by Nathaniel Howe, 2011).

Three dead blocks were found on the upper gundeck. Two of them were well aft near the mizzenmast (Fnrs 04729 & 05616). The first of these is the smallest block recovered from the entire ship, measuring only 83mm in length and cut to carry cordage of less than 18mm in diameter. The other dead block found on the aft portion of the deck is much larger, totaling 149mm in length and capable of handling cordage up to 36mm. The third dead block (Fnr 07759) was found up forward, just abaft the foremast, on the port side. It measures 166mm in length, is made of ash, and has a 36mm swallow.

Both of the enormous ram's head blocks found on *Vasa* were on the upper gundeck, lying almost directly below their original positions in the rig. The larger of the two (Fnr 09843) lay just abaft and to port of the mainmast. The slightly smaller example (Fnr 08008) lay abaft the foremast. At the time of recovery, both still contained the graphitized remains of the iron sheaves and remnants of cordage.

Two Dutch-style upper lift blocks were also recovered from the upper gundeck. The first (Fnr 04348) was found between the main and foremasts and has a shell measuring 433mm in length. Its swallow, however, is only 34mm in diameter—5mm narrower than the other, shorter-shelled, 424mm upper lift block (Fnr 03741) found immediately to starboard of the mainmast. Both are made from ash and carved with smooth, rounded edges.

A large, open-swallowed, *sub-type 11*, single block, or snatch block (Fnr 08692), was recovered from the base of the foremast. Carved of oak, it measures 832mm in length and can carry heavy cordage up to 70mm in diameter. At its head, the block is cut with an eyehole for fastening a pendant.

Forty-four block fragments lay on the upper gundeck as well. Although many were violently broken by salvage efforts or secondary depositions, as much as a third of the fragments were simply the eroded remnants of blocks exposed to the harbor's currents. Shell fragments, sheave fragments, and combinations thereof accounted for 77% of the block parts found on the upper gundeck. Only eight intact sheaves were recovered from this area. Three of these were short-grain *lignum vitae* (Fnrs 07587, 08697, &8941) rather than the long-grain ash sheaves found in all of the ship's intact blocks.

Lower Gundeck

The lower gundeck was the highest deck still enclosed at the time of excavation. The distribution of blocks on this deck had therefore been far less disturbed than on the decks above. A total of 104 blocks and 11 fragments were recovered from the lower gundeck (Figures 7.6, 7.7, and 7.8). The majority were single blocks and double blocks, but several specialized blocks were also recovered.

In total, 52 single blocks were distributed on the lower gundeck. The most common type were *sub-type 1* single blocks, averaging 230mm in length with elliptical shells and chamfered edges. Forty-nine of the single blocks were of this type and size. Many lay in pairs near the gunports and some were even still attached to or closely associated with gun carriages. These associations were particularly clear at gunports 4, 5, 7, 9, 11, 15, 17, 18, 19, 21, 22, and 26. Pairing of single blocks at the other gunports was less clear due to disturbance of the material. Nine of the *sub-type 1* single blocks on the lower gundeck are ash. The rest are made of oak. All but eight of the blocks have a recess carved out of the heel to seat a becket. Yet, half of these exceptions are so heavily eroded that any evidence of a becket recess has been long lost.

Four of the single blocks found on the lower gundeck are of other sizes or sub-types. One of the *sub-type 1* single blocks (Fnr 11659) is notably larger than the others, measuring in at 276mm in length. It was found just abaft the foremast and has a shell made of ash. A large, flat, lenticular *sub-type 4* single block (Fnr 11782) was found roughly amidships on the starboard side. Also made of ash, it measures 486mm in length and can carry cordage up to 48mm in diameter. A pair of *sub-type 2* single blocks were also found. These rounded ash blocks with squared ends were both 151mm in length. The first (Fnr 08788) lay on the starboard side beside the mizzenmast, the second (Fnr 07714) was on the port side, but its distance from the bow was not recorded.

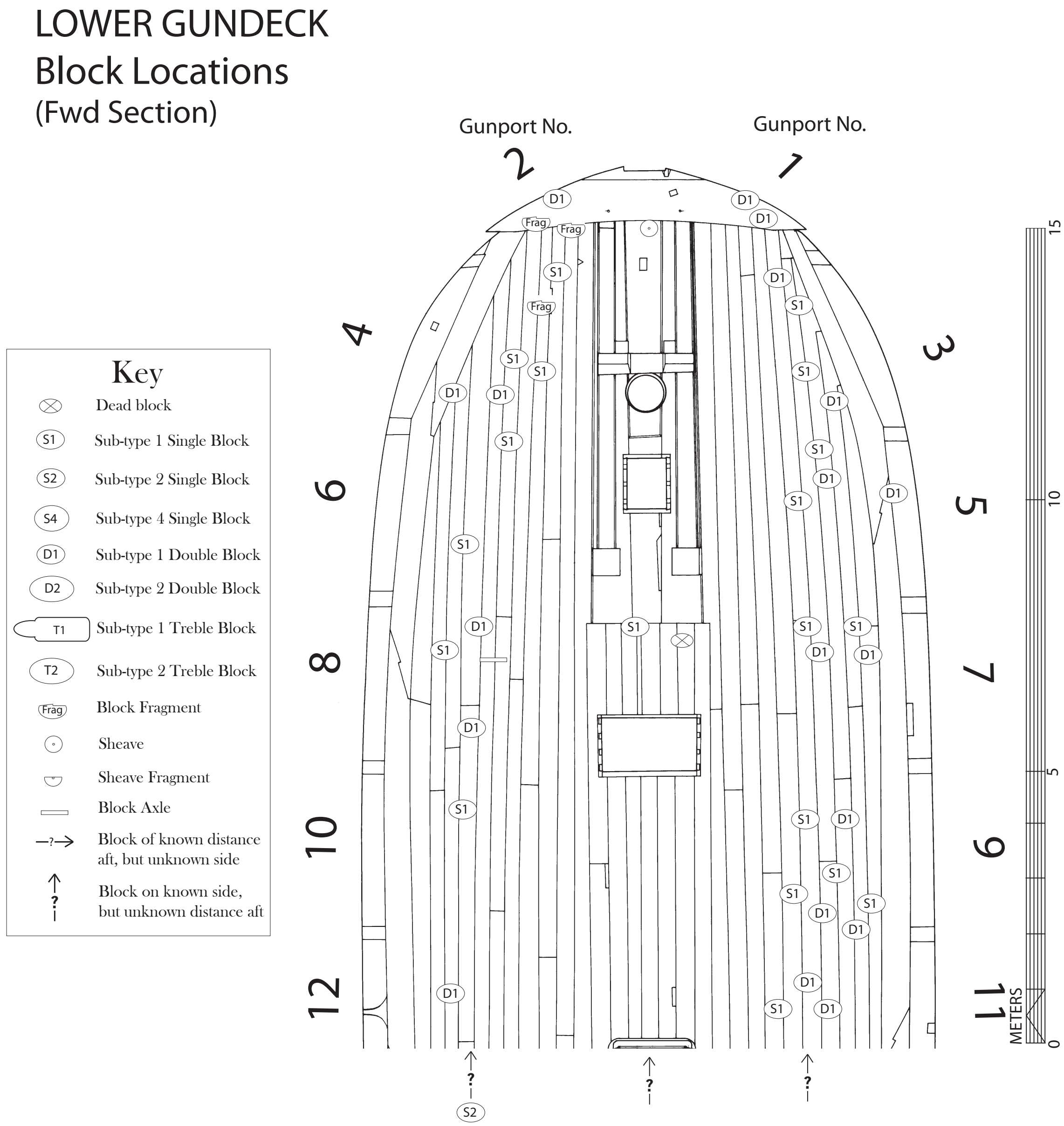


FIGURE 7.6. Find locations for blocks on forward section of the lower gundeck (Illustration by Nathaniel Howe, 2011).

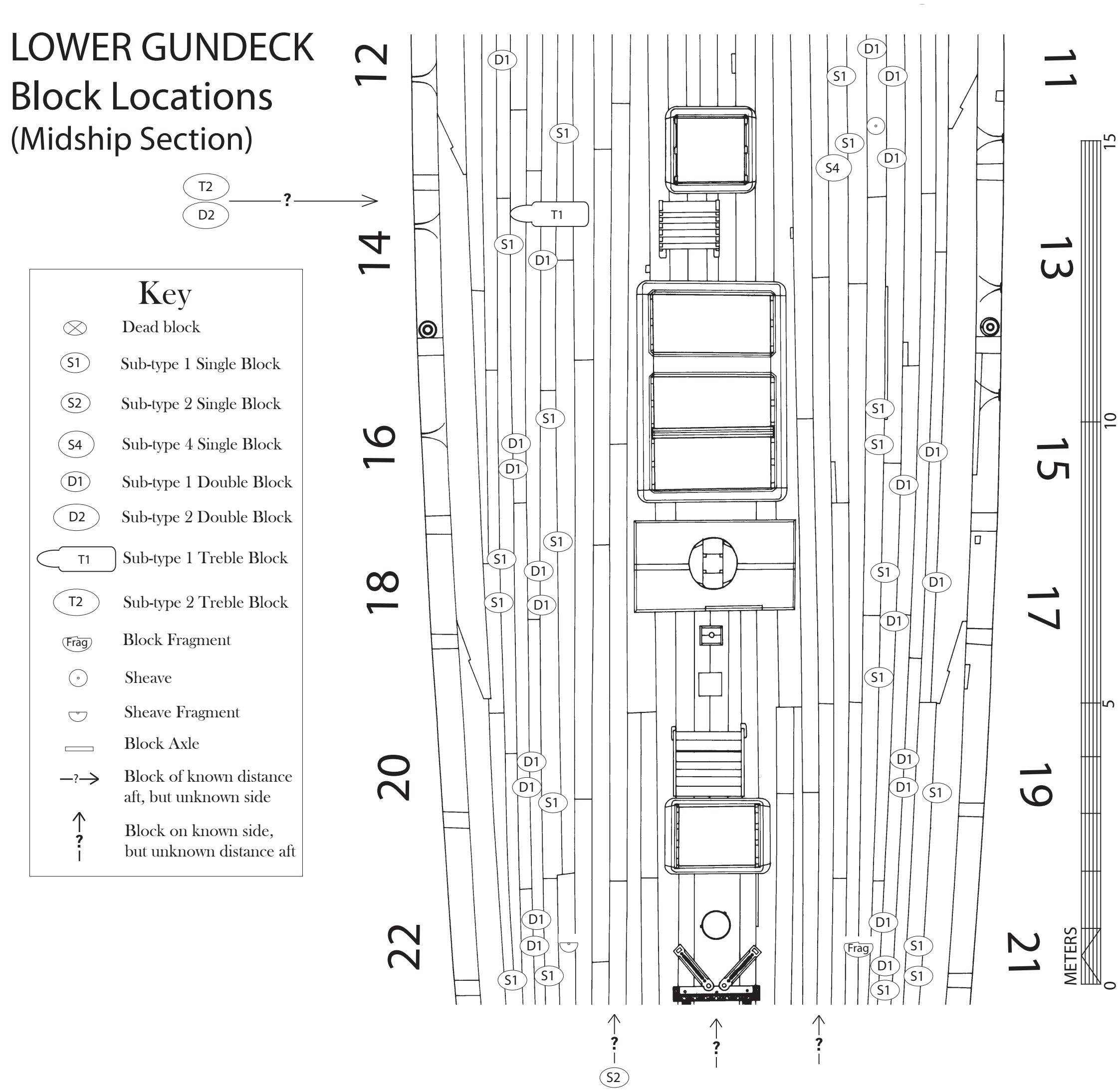


FIGURE 7.7. Find locations for blocks on midship section of the lower gundeck (Illustration by Nathaniel Howe, 2011).

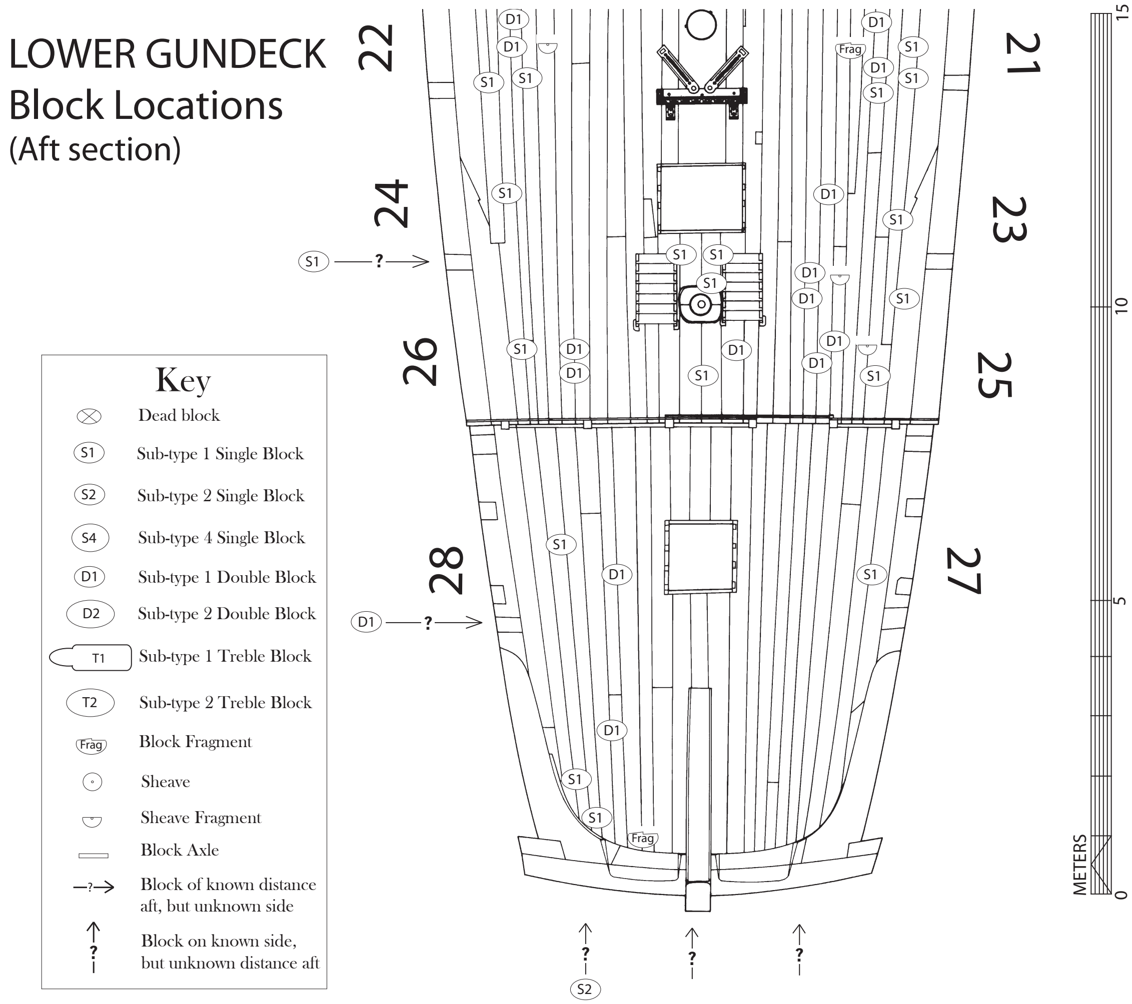


FIGURE 7.8. Find locations for blocks on aft section of the lower gundeck (Illustration by Nathaniel Howe, 2011).

Dispersed among the single blocks were 49 double blocks. Forty-eight were *sub-type 1* double blocks. All of these were made of oak, except one in ash (Fnr 11430). Like the single blocks, these were distributed somewhat evenly throughout the gundeck and generally paired near the gunports, sometimes still being attached to or closely associated with a particular gun carriage. The clearest cases were at gunports 1, 4, 5, 7, 8, 9, 11, 15-22, 25, and 28.

The only double block of a different form found on the lower gundeck was a very large, *sub-type 2,* double block (Fnr 12885). It is 481mm long, made of ash, and cut with smooth, rounded edges. Its swallows are cut to accept a fall up to 48mm in diameter and its over-proportioned strop score is 85mm wide. The block was located on the starboard side just inboard of gunport 13, near the main hatch.

Beside the enormous double block lay an even larger triple block carved in the same style (Fnr 12884). The triple block measures 483mm in length and 330mm in breadth. Unlike its corresponding double block, it is made of oak and has 55mm swallows. Another triple block of even greater size (Fnr 10923) lay directly across the deck on the port side. This block has 73mm swallows and the classic Dutch ram's head block form, differentiated from *Vasa's* ram's head blocks by having three sheaves instead of four.

The only other block type found on the lower gundeck was a lone dead block (Fnr 11658). It was located amidships, abaft the foremast near the lower gundeck capstan. Made of ash, it measures 167mm long and could carry a fall of 34mm.

Only a handful of block fragments were scattered on the lower gundeck. A sheave and a few broken pieces of a block shell lay in the extreme bow, one sheave lay amidships to starboard, and a few sheave fragments lay in the vicinity of the tiller compartment.

Orlop

Sixty-three blocks and block parts were located on the orlop, the third highest quantity of any major find area of the site (Figures 7.9, 7.10, and 7.11). Over 90% of these finds were located in two compartments near the stern on the port side, designated compartments T3 and T5. Six of *Vasa's* sails and a variety of other specialized rigging hardware were also found in compartment T3 (See Volume I, chapter 14).

Lightly constructed partitions divide the orlop into five compartments. During excavation, these were designated T1 to T5, counting aft from the bow. No blocks or fragments were found in T1 at all. Compartment T2 contained only three blocks despite being the largest space on that deck, running most of the length of the ship from beam four to beam 22. One is a mid-sized dead block made of ash (Fnr 18880), found on the port side amidships. The other two are standard *sub-type 1* single blocks. One rested on the starboard side approximately one quarter of the deck's length from the bow and the other lay near the aft end of the compartment.

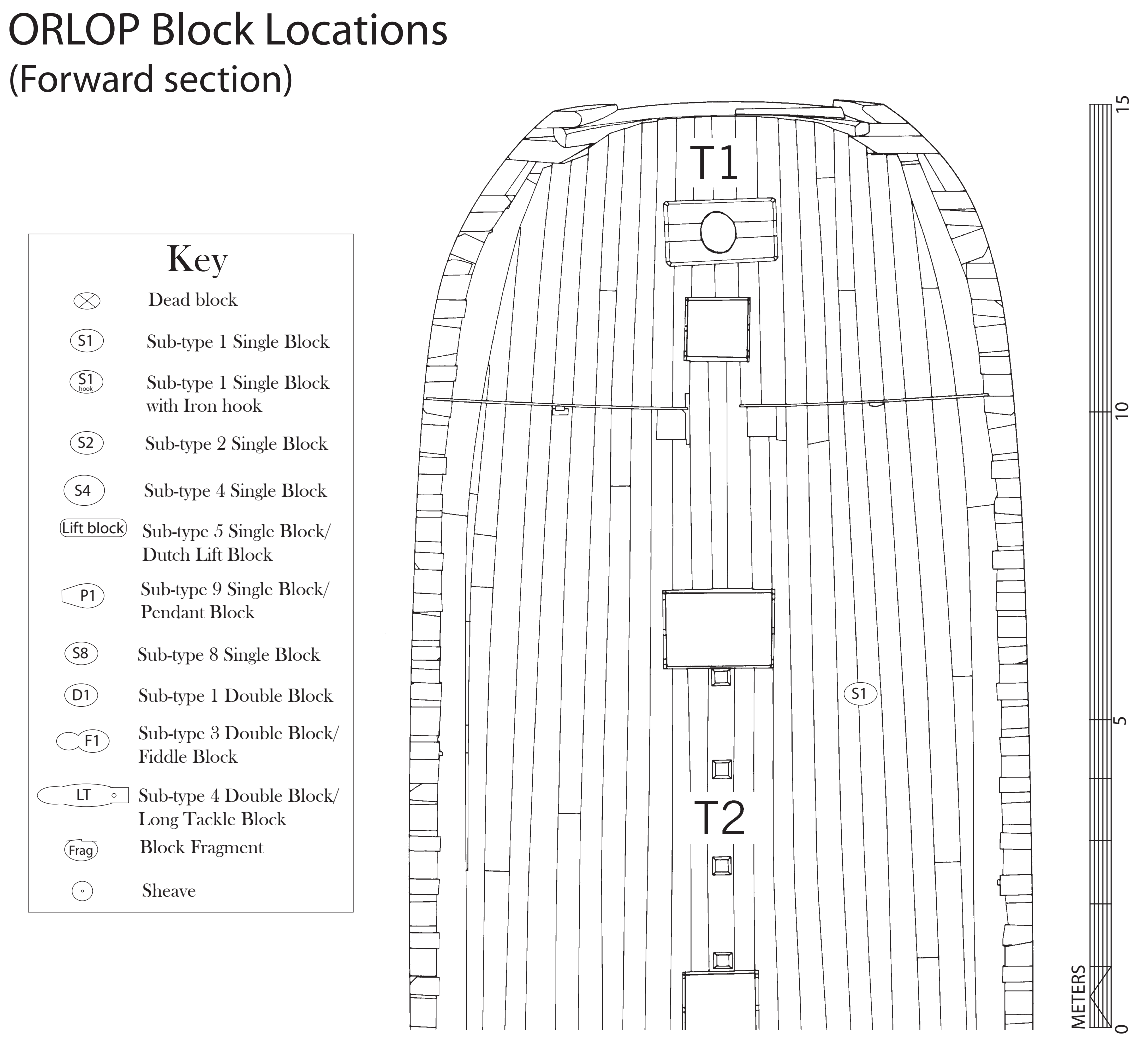


FIGURE 7.9. Find locations for blocks on forward section of the orlop (Illustration by Nathaniel Howe, 2011).

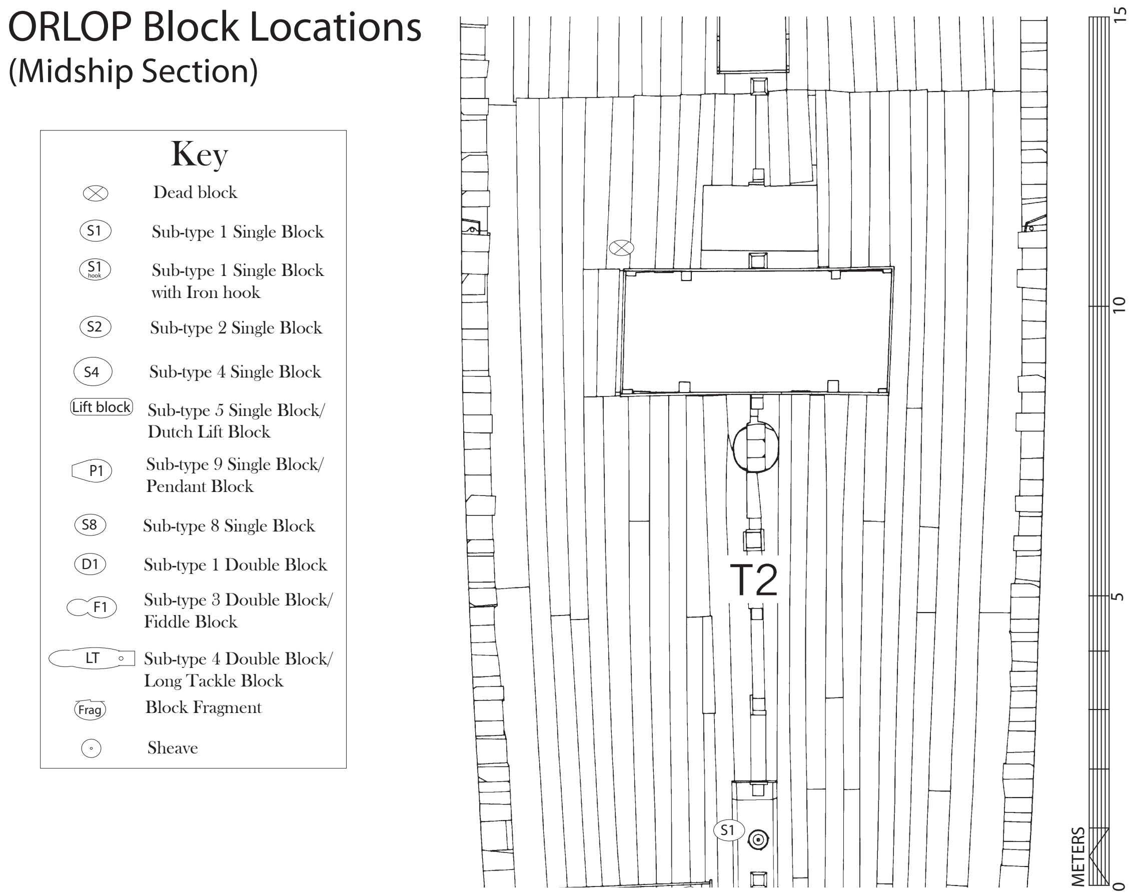


FIGURE 7.10. Find locations for blocks on midship section of the orlop (Illustration by Nathaniel Howe, 2011).

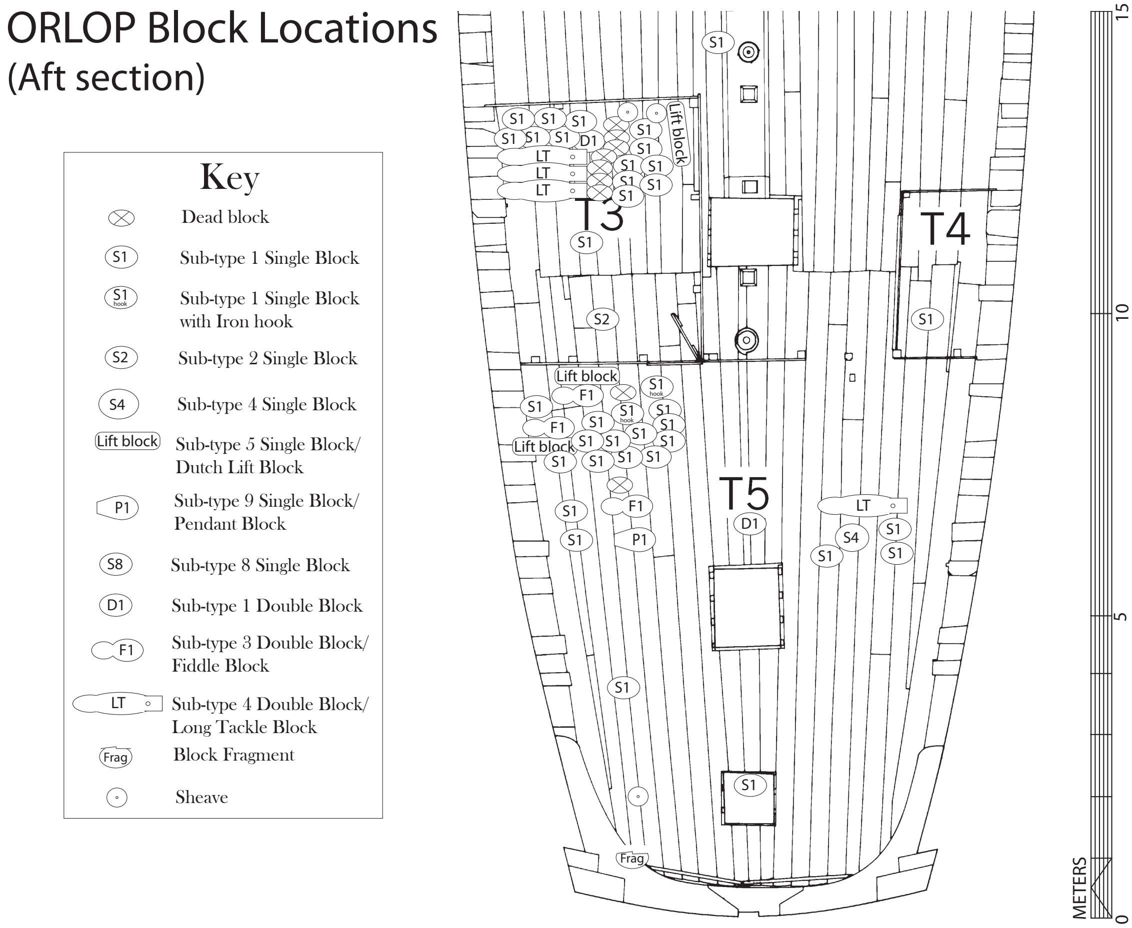


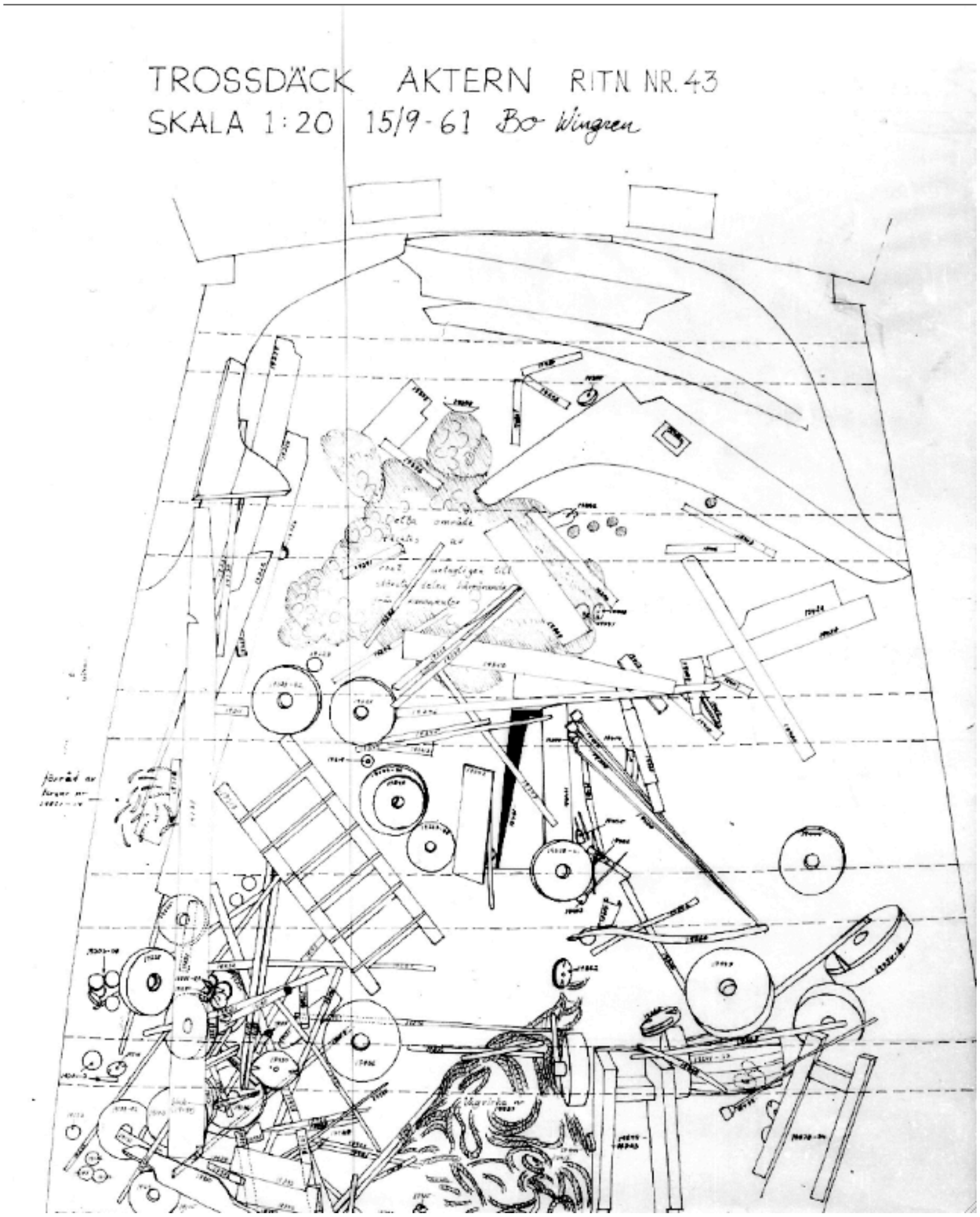
FIGURE 7.11. Find locations for blocks on aft section of the orlop (Illustration by Nathaniel Howe, 2011).

Compartment T3, however, was piled deep with sails and rigging hardware. Twenty-seven blocks of six types and two loose sheaves were packed into this small compartment on the port side that measures scarcely 4.3m long. Thirteen *sub-type 1* single blocks with elliptical shells and chamfered edges were in this compartment. Nine are made of ash while the rest are oak. Only one has a becket recess cut into the foot. Other blocks in compartment T3 included a large *sub-type 2* single block with rounded edges and squared-off ends (Fnr 18628), a standard double block (Fnr 18906), and seven dead blocks. The dead blocks consist of four different sizes, at least two of those sizes being represented by a pair of matching dead blocks. Wood species varied regardless of size or pairing, five of the dead blocks being made of ash and two of oak. Three non-stropped long tackle blocks (*sub-type 4* double blocks) were also in the compartment (Fnrs 18904, 18908, & 18982). All were made of ash and cut for 30mm cordage, but varied in length by 50mm. Two loose sheaves and a lone Dutch-style upper lift block (Fnr 18901), 336mm in length with a 33mm swallow, were also present.

The rest of the blocks on the orlop were in compartments T4 and T5. On the starboard side opposite T3, compartment T4 contained only a solitary *sub-type 1* single block (Fnr 17987). Compartment T5, however, held 32 blocks, plus two fragments (Figure 7.12). The majority of these blocks were concentrated in the forward part of the compartment on the port side. In order of complexity, the compartment contained a matching pair of dead blocks with 38mm swallows. Surrounding these was a total of 19 standard *sub-type 1* single blocks and two larger examples modified for iron strops (Fnrs 19904 & 19906). There were also three common fiddle blocks (Fnrs 23885, 18775, & 19365), and one of the rare non-stropped long tackle blocks (Fnr 19234). Near these lay a standard double block (Fnr 19362) and two Dutch-style upper lift blocks (Fnrs 19717 & 20000), including one that is rather crudely cut from birch. A small crane block (Fnr 19905) was also in the compartment as was a loose sheave and a block shell fragment.

Although only eight blocks were required on the orlop to manage the two stern chaser carriages, more than 60 blocks were present. These were heavily concentrated in compartments T3 and T5 where much of the ship's other rigging materials were found. Accounting for just over 13% of the entire block collection, these assemblages contained

50% of all the fiddle blocks, more than half of the dead blocks, and all four of the non-stropped long tackle blocks recovered with *Vasa*.



7.12. The blocks among the debris in compartment T5 (Drwing by Bo Wingren, courtesy of the Vasa Museum).

Hold

Deep in the ship, far below the sailing rig and gun carriages, an additional 44 blocks and 16 fragments lay hidden away in *Vasa*'s hold (Figures 7.13, 7.14, and 7.15). These were distributed among eight of the hold's nine compartments and consist of 33 single blocks, 10 double blocks, one dead block, and an assortment of sheaves and shell fragments. Sixteen of the blocks recovered from the hold are ash, including one *sub-type 1* double block (Fnr 15255). This was one of just four examples of a *sub-type 1* double block made of ash on the entire ship. All the other blocks in the hold were oak. In contrast to the single blocks on the gundecks, only three of those found in the hold have a becket cavity carved out of the foot. None of these three was in the same compartment as another.

The largest concentrations of blocks in the hold were in compartments H8 and H9 in the stern. There is no partition between these spaces, but H9 is differentiated by an elevated platform. Combined, H8 and H9 contained 20 single blocks, eight double blocks, and one block shell fragment. These were clustered all the way aft on the starboard side, neatly stacked on top of a quarter knee. Interestingly, every one of the blocks in H8 and H9 was broken, split, or defective in some way. One has an axle that was too short (Fnr 14897), another has a split shell and a broken axle (Fnr 15251), there is a double block with a badly warped sheave (Fnr 15255), and one of the single blocks has an axle but is missing its sheave, suggesting the sheave split and fell out (Fnr 16735). A particularly fascinating single block found in this area has a deep notch in the shell beside the swallow, indicating that the fall jumped off the sheave and chafed through the edge of the shell (Fnr 15375).

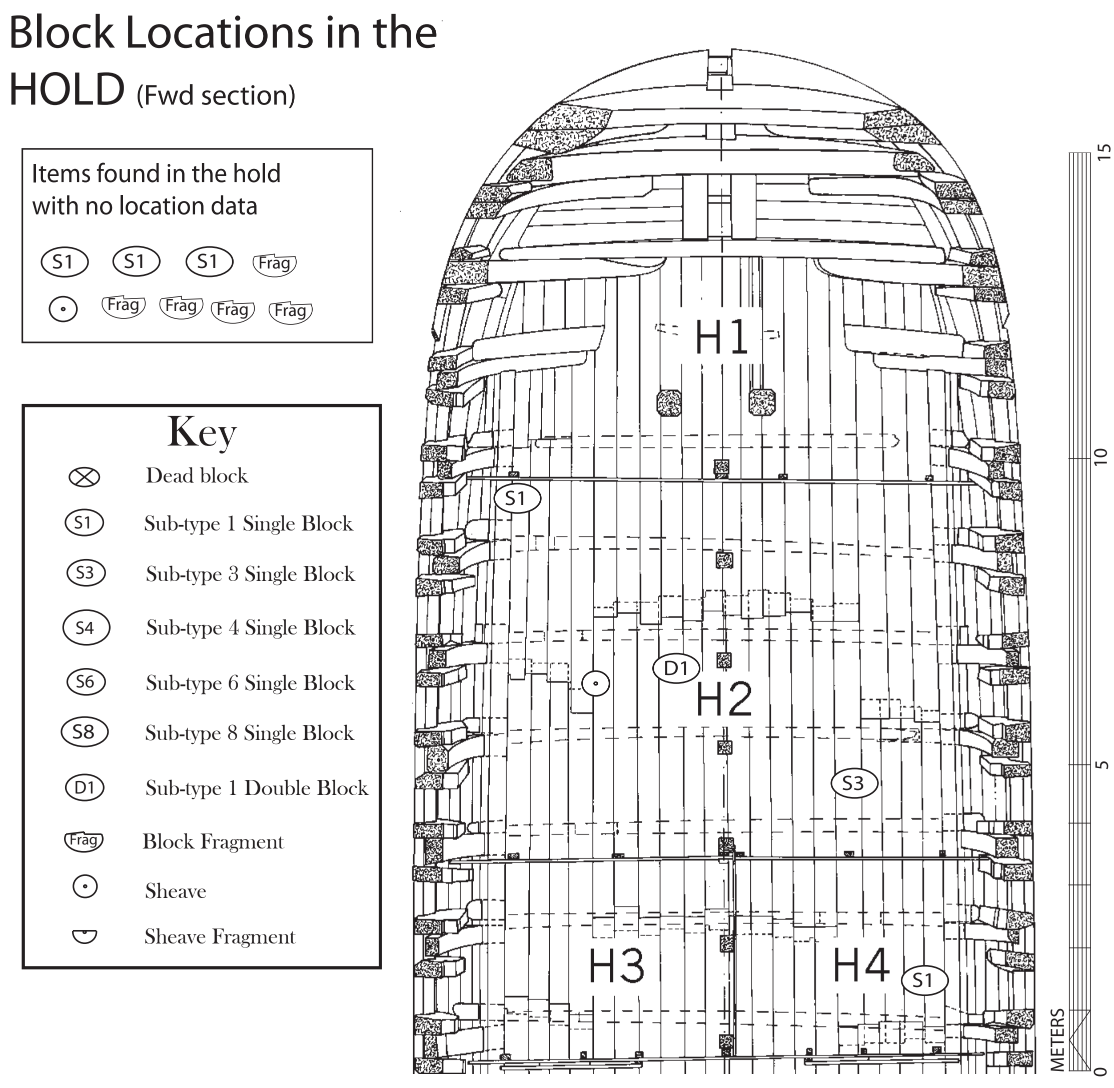


FIGURE 7.13. Find locations for blocks on forward section of the hold (Illustration by Nathaniel Howe, 2011).

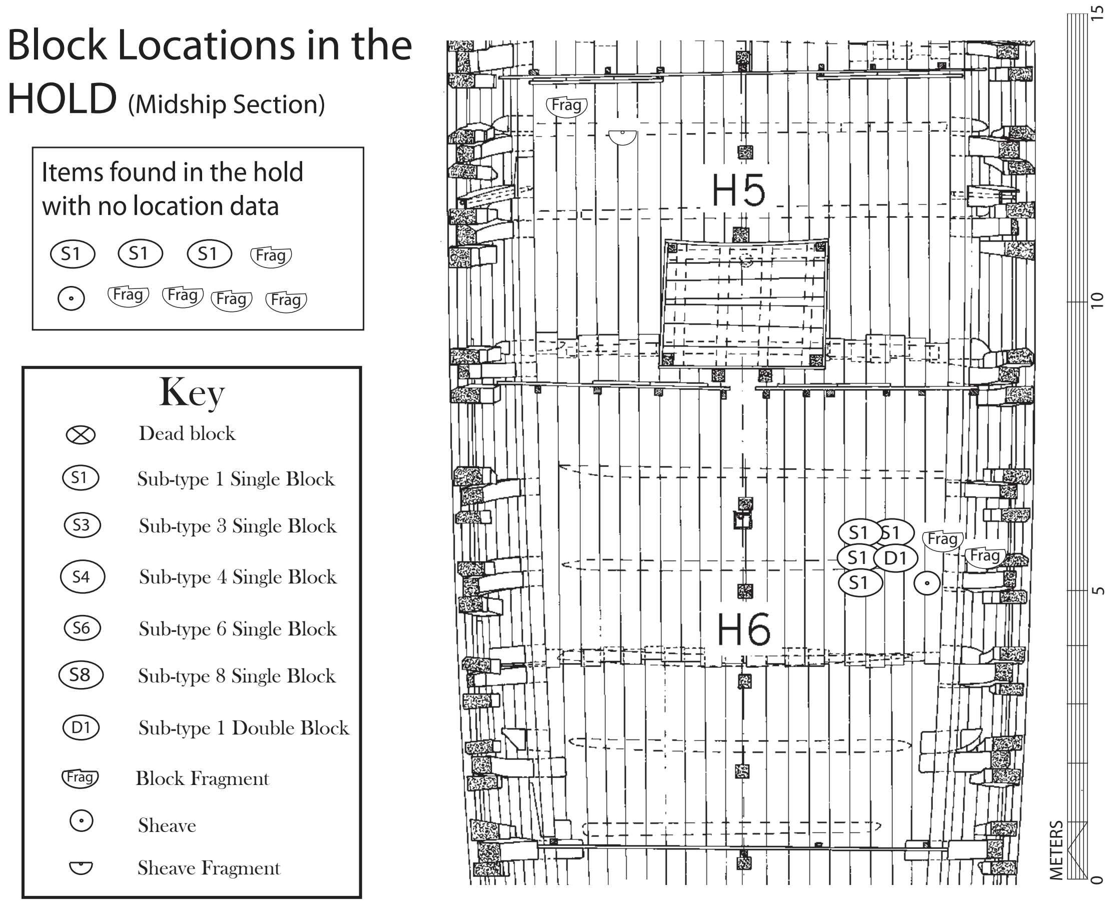


FIGURE 7.14. Find locations for blocks on midship section of the hold (Illustration by Nathaniel Howe, 2011).

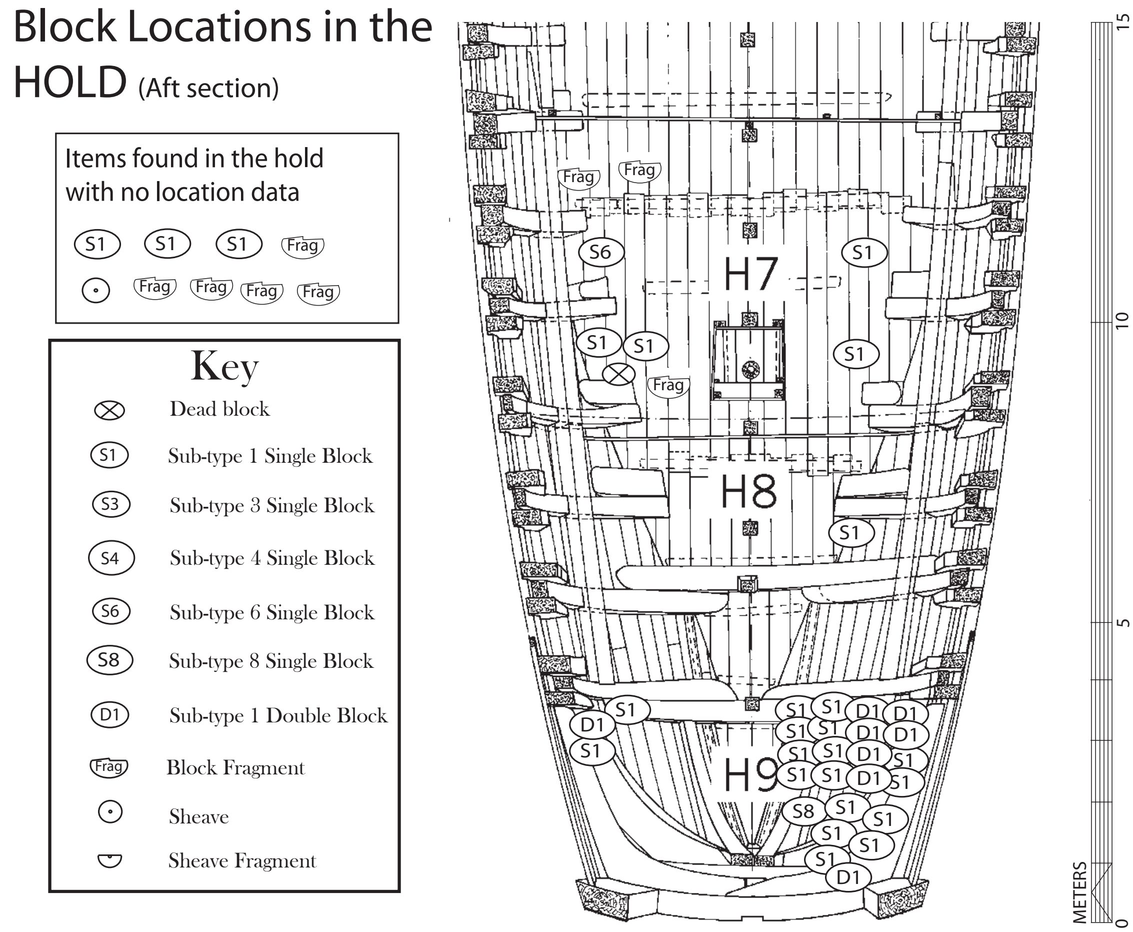


FIGURE 7.15. Find locations for blocks on aft section of the hold (Illustration by Nathaniel Howe, 2011).

Just forward of H8, compartment H7 contained five single blocks, one dead block, and three block shell fragments. These were distributed more or less evenly throughout the compartment. The dead block (Fnr 15760) is a small to mid-size example, measuring 162mm long, made of oak, and carved with a 35mm swallow.

Compartment H6, just abaft amidships, contained five blocks and three fragments. Four of these are *sub-type 1* single blocks. Another is an unusually small, oak, *sub-type 1* double block (Fnr 12440). The three fragments include a sheave, a shell fragment, and a cheek from a *sub-type 2* single block (Fnr 12417).

Even fewer blocks were found in the forward compartments. Compartment H5 contained only a sheave fragment and a piece of shell and axle. A solitary *sub-type 1* single block was all that lay in H4 and no blocks whatsoever were found in H3 (filled with barrels of meat). Compartment H2 held two *sub-type 1* single blocks, one standard *sub-type 1* double block, and a loose sheave. No blocks or fragments were found in H1. By far, the majority of the blocks in the hold were in the stern in H7, H8, and H9.

Debris Field Around the Hull

As *Vasa*'s expansive rig collapsed, many of its more than 250 rigging blocks missed the narrow upper decks and fell into the mud around the ship. Fifty-two were found buried in the sediments near the hull in the late 1950s and early 1960s (Figures 7.16 and 7.17). These included more major block types than any other find area on the site.

Blocks were scattered along both sides of the hull, but the largest concentration lay just in front of the bow. Six standard *sub-type 1* single blocks ranging from 175mm to 260mm in length and a pair of *sub-type 2* single blocks rested near the stem along with two *sub-type 1* double blocks (Fnrs 20794 & 20452). Among them were two massive *sub-type 1* single blocks fitted with iron hook strops (Fnrs 20517 & 20526). One of them (Fnr 20526) was concreted to one of the ship's bower anchors (Fnr 20525). The heavy forged iron fittings survived the ship's three centuries on the bottom and were still clutching the 480mm wooden block shells when recovered. Nearby, a common fiddle block (Fnr 20795), a Dutch-style upper lift block (Fnr 20527), and a 417mm, double-sheaved, ash crane block (Fnr 20244) also lay under the bow. Additionally, there was a dead block (Fnr 20490) and a large snatch block that still had its clasped, iron strop and was fitted with a *lignum vitae* sheave (Fnr 20746). Three shell fragments and a loose sheave were also scattered in the vicinity of the bow.

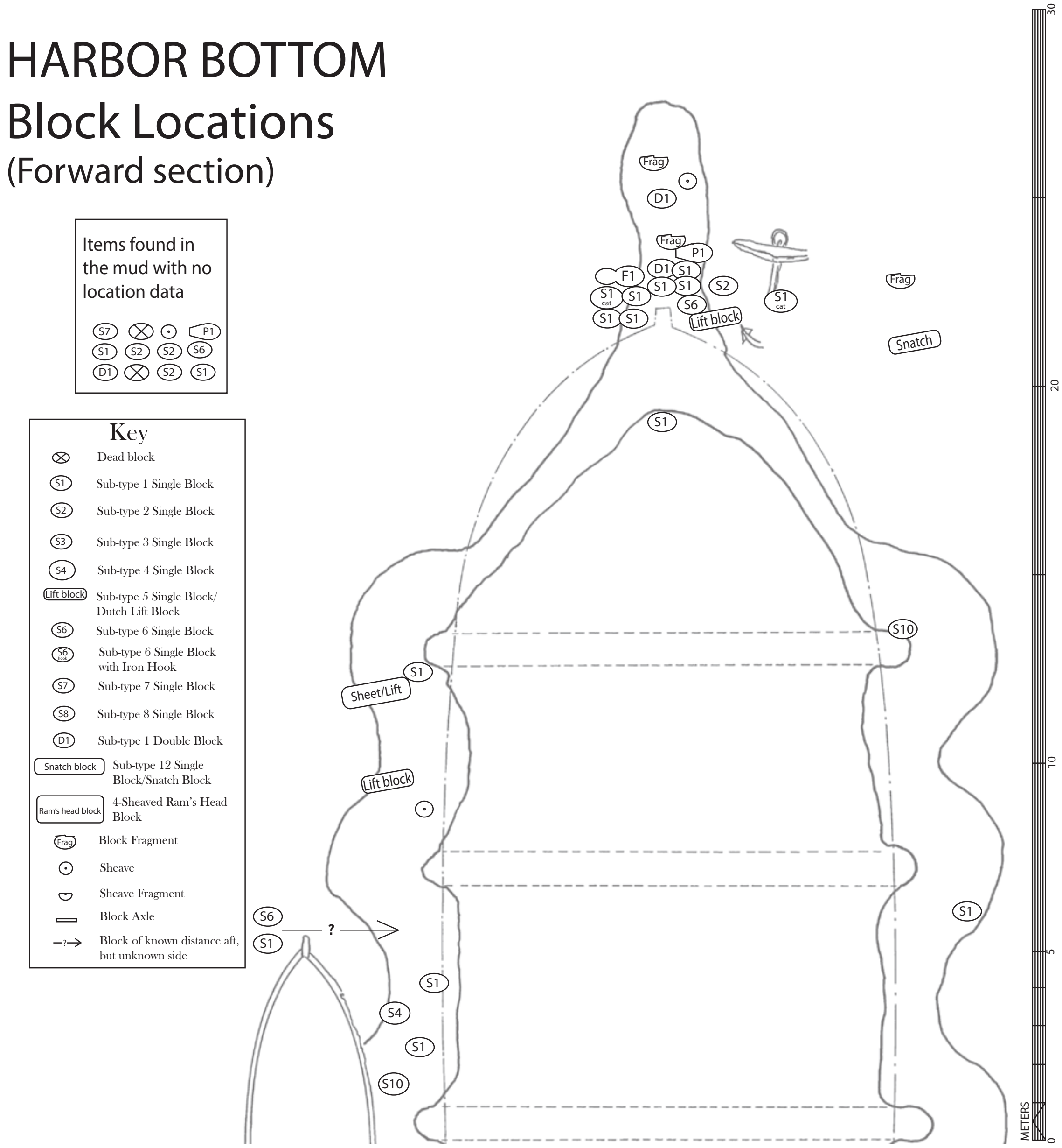


FIGURE 7.16. Find locations for blocks in forward section of the debris field (Illustration by Nathaniel Howe, 2011).

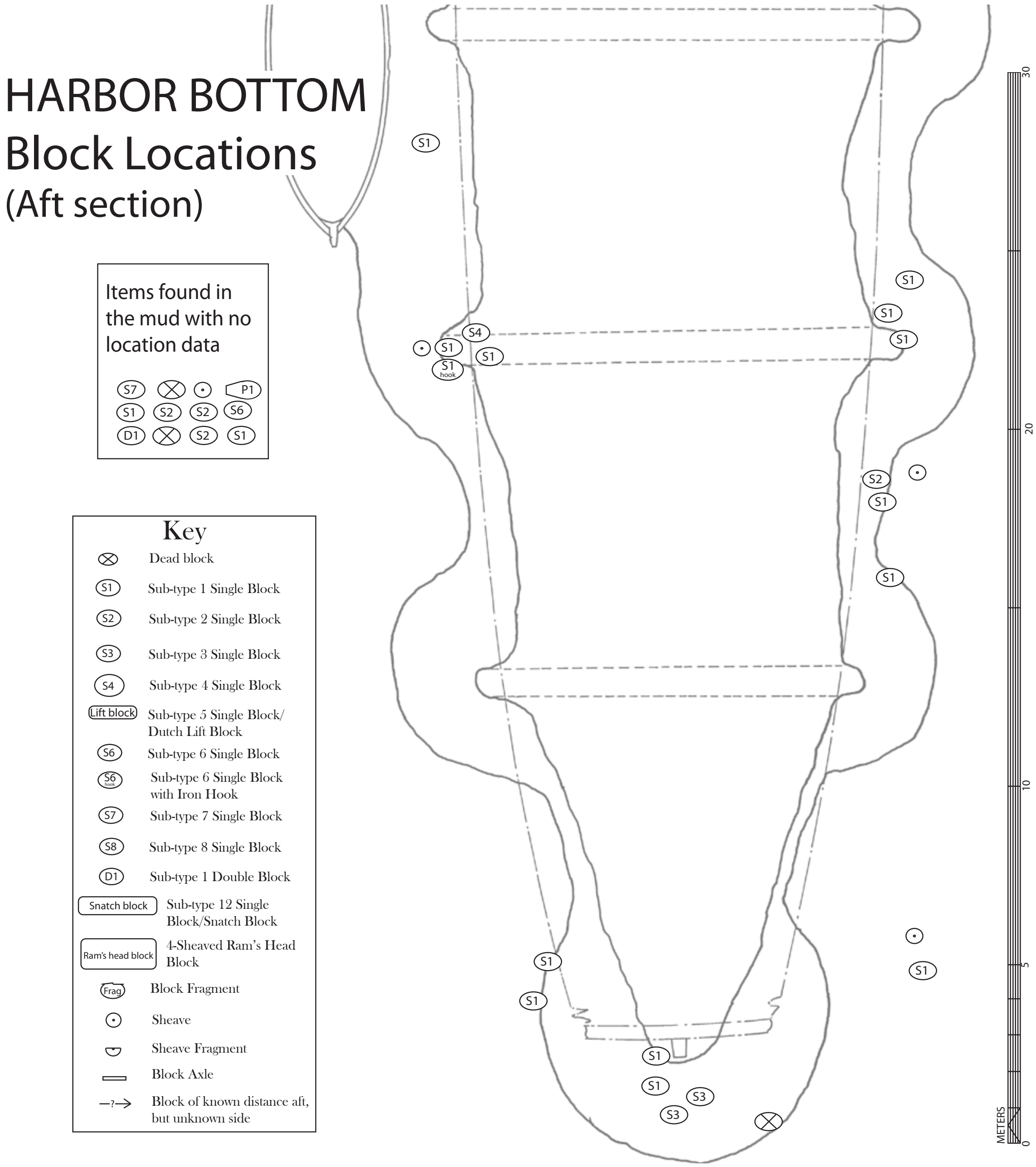


FIGURE 7.17. Find locations for blocks in aft section of the debris field (Illustration by Nathaniel Howe, 2011).

Abeam of the foremast, several specialized blocks were found. To starboard there was a Dutch-style upper lift block (Fnr 21454) and a heavily built, thick-walled, *sub-type 10* single block (Fnr 00688). A matching block (Fnr 23504) was found 15-25 meters aft on the port side. A large, *sub-type 1,* ash, single block (Fnr 23358) and a loose sheave were also recovered on the port side abeam of the foremast.

Midway between the main and foremasts (which side of the ship is unknown) lay a very large, 525mm, *sub-type 2* single block with rounded edges (Fnr 23465). Four small to mid-size *sub-type 1* single blocks with chamfered edges were also in this area—two to starboard and two to port. A large, flat, *sub-type 4* single block with a broad, thin ash shell was found to port in Tunnel B. Close by lay the only Dutch-style, combined topsail sheet and lift block found in association with *Vasa* (Fnr 23455). The massive 715mm-long block still retained one of its sheave and axle sets.

Another eight blocks were recovered from the mud in the vicinity of the mainmast. The largest is a 478mm, *sub-type 1* single block found on the port side in tunnel D (Fnr 00112). It has a score cut for a heavy, 65mm-wide iron strop and its swallow can accept a fall up to 80mm in diameter. The other blocks in this area include six standard *sub-type 1* single blocks distributed evenly on port and starboard, one *sub-type 2* single block on starboard (Fnr 21738), and two sheaves, one on each side.

A handful of blocks fell in the mud around the stern of the ship, including eight single blocks, one dead block, and one sheave. The single blocks are roughly evenly distributed around the stern and consist of six standard *sub-type 1* and two rounded *sub-type 2* single blocks. All but one are made of ash. Just off the stern lay a tiny 85mm dead block (Fnr 405) and a small, 57mm sheave (Fnr 01357).

The find location of another nine blocks found in the mud was only cursorily recorded. Some of these are distinctive types key to reconstructing the placement of *Vasa*'s rigging hardware. One is a specialized, flat, *sub-type 4* single block (Fnr 20518), and two others are dead blocks (Fnrs 23257 & 20490). The only readily identifiable block from this area is one of the ship's two massive cat blocks (Fnr 20526), concreted to one of the anchors.

Untraceable blocks

The above section accounts for 85% of the blocks and block fragments recovered from the *Vasa* wreck site. Unfortunately, find information is missing for the remaining 15% of the block collection. Most of these lost their find tags during conservation, but some just were not carefully recorded during the early phases of the salvage work. The untraceable items include 28 single blocks, three double blocks, a fiddle block, a crane block, and nearly 60 fragments. For some of these blocks, relative find locations can be deduced by matching the find number to artifacts from the same part of the numbering sequence that have known locations. The numbering system is a relatively reliable indication of where the excavation team was working at any given point in the project; however, it is still an estimate and cannot be considered truly reliable data.

Chapter 8. Reconstruction and Interpretation

Challenges to Identification and Interpretation

Reconstructing *Vasa*'s rigging plan and determining where various blocks were employed is difficult to accomplish based on the physical evidence available. Unlike the beak head or even the sculptures decorating the stern, few of the rigging remains ended up directly below their original positions on the ship. Determining their proper locations is further complicated by the fact that they are independent pieces of hardware and are not nailed or bolted to another surface, offering fastener holes to align and confirm location. During *Vasa*'s three centuries on the harbor bottom, the rigging was heavily disturbed and some portions of it entirely removed or destroyed. By the late 1950s, only a confusing field of debris remained to represent the complex network of lines and spars that once stretched over *Vasa*'s hull.

The process of reconstructing *Vasa*'s rigging configuration begins with the scant historical evidence. Although there are no drawings of *Vasa* or its rig, there are written sources offering clues about its configuration. In 1626, the Crown signed a contract with master rigger Admiral Richard Clerk to direct and oversee the rigging of all ships of the Swedish fleet calling at the Stockholm navy yard. His contract states that the ships under his charge were to be rigged and fitted out in the "manner of the best Holland warships" (*Riksarkivet* 1626:Folio 107r (§ 4), lines 1-12). It can therefore be anticipated that the configuration of *Vasa*'s rig and the placement of blocks most likely conforms to Dutch practice as recorded by contemporary ship models, knowledgeable painters such as the two Willem Van De Veldes, and scholars like R. C. Anderson (Anderson 1927). Those on contract at the Stockholm navy yard seem to have followed such orders closely as

Vasa's hull, also directed to be built in Dutch fashion (Cederlund 2006:42), is classically Dutch in form and general construction.

Turning to archaeological evidence of the rig, the masts and surviving deck fittings such as sheaved fairleads, knightheads, and pin rails offer clues about the arrangement of the elements actually rigged aloft. Most of these items were found close to their original locations and provide key information about the rest of the rig. These fittings and the overall rigging reconstruction have been examined in detail since the ship was raised, resulting in the rigging reconstruction shown in Figure i.1 at the beginning of this thesis. Based on this reconstruction and the knowledge that the configuration of the rig was supposed to emulate Dutch practices, the types of blocks, their general find locations, and their original placement and function can be anticipated to some degree—enough to either support or refute the assumption that Clerk (a Scotsman) rigged *Vasa* in Dutch fashion as ordered (Cederlund 2006:41).

Accurately placing the blocks and other rigging hardware in the rig is severely complicated by the scale of the damage wrought upon the rig during the ship's 333 years on the harbor bottom. The destruction of *Vasa*'s rig began immediately after the sinking. Lying at a depth of 32 meters, the ship's masts projected more than 10 meters above the water. The exposed upper rig, still adorned with flags and banners, was an embarrassment to the naval establishment and the crown while also containing a sizable quantity of valuable sailcloth, spars, and tackle that could be salvaged for the fleet. Although the details of exactly when the upper rig was cut away are no longer known, the easily accessible topsails and topsail yards above the surface were probably the first to be reclaimed. How much was removed below the surface is harder to estimate. If breathhold divers or a diving bell were employed to recover rigging, then it is possible that the entire topmasts and perhaps even the course yards could have been recovered and any entangling cordage cut away. The presence of the course yard parrels, the topmast deadeyes, and one of the combined-topsail-sheet-and-lift blocks, however, suggests that the salvage of the rig did not progress that far below the surface.

After salvaging the accessible elements of the rig, efforts turned to salvaging the rest of the ship. It was probably during this phase that much of the destruction of the rig below the surface occurred. Work began in earnest in the days and weeks after the sinking when salvor Ian Bulmer and his crew set to work trying to right the ship. Securing tackles to the topmasts, his team used the rig for leverage to roll the ship upright. Shortly thereafter, Willem de Besche was contracted to attempt to raise the hull, swinging anchors into the ship's sides and securing them to barges and the aged warship *Svärdet* for use as a floodable lifting pontoons. This effort certainly inflicted heavy damage on *Vasa*'s lower rig as the large iron anchors that missed the hull tore through spars, lines, and sails. Then the navy took over the effort, directing Admiral Klas Fleming to attempt to lift the hulk by the same method in a second attempt. This work further compounded the damage to the rig (Hafström 2006:69, 70).

Further heavy damage to the rigging occurred during Treileben and Peckell's salvage work in the 1660s when salvagers descended to the wreck in a diving bell. Armed with cutting implements and heavy tackles rigged to the surface, they cleared away any spars, rigging, or abandoned salvage gear strewn across the decks that might interfere with the extraction of *Vasa*'s cannon (Cederlund 2006:84). The aggressive work undertaken during that period likely demolished most of the remaining rigging, including the heavy shrouds that barred access down to the gundecks and perhaps even the mainmast and the bowsprit with its web of lines that hung over the forward gunports (Fred Hocker 2011, pers. comm.). In the process, Treileben and Peckell's work complicated the identification and interpretation of *Vasa*'s rigging remains by disturbing and relocating many of the extant artifacts, throwing blocks and spars overboard, or knocking them down onto the upper gundeck.

The blocks and other rigging elements that remained after these salvage efforts were subsequently exposed to environmental damage. Particulates suspended in the current slowly eroded the surfaces of the wood, sometimes reducing blocks to nearly unidentifiable nuggets (Figure 8.1). The resulting loss of indicative details including shape, chamfering, beckets, and specialized strop scores further limits the identification and interpretation of at least 10% of the block collection. Severe erosion proves particularly problematic when trying to identify patterns of standardization in block dimensions. Erosion reduces the shell size, but increases the diameter of the swallow. The inverse impact of erosion on these two dimensions rapidly amplifies error in the key diagnostic ratio of shell length to swallow diameter such that even moderately eroded blocks cannot provide an accurate ratio for comparison in order to judge the level of standardization in block production.

Figure 8.1. A severely eroded, almost unidentifiable block. The long piece at the bottom is one of the cheeks of the block shell, the slab on top of it is a disfigured sheave, and the axle can be seen running vertically through the other two pieces (Photo courtesy of the Vasa Museum).

Identification and Reconstruction

The violent disruption of the rigging and upper decks while *Vasa* lay on the bottom poses a significant challenge to reconstructing the ship's rig and determining the original placement and function of individual blocks. Yet, careful analysis of the type, size, style, and distribution of *Vasa*'s blocks on the site can still offer clues as to where certain blocks were most likely rigged. This analysis begins by identifying and interpreting large groups of blocks that can be readily separated from those used in the actual sailing rig the day *Vasa* foundered. Following that is an examination of *Vasa*'s actual rigging blocks and the potential placement and configuration of specific blocks and tackles or at least certain block types. Suspicious block finds that are unlikely to be part of *Vasa*'s original rig are discussed last, after the placement of all other blocks has been covered.

Gun Tackle Blocks

The largest and most clearly defined group of blocks from *Vasa* is actually associated with the ship's armament rather than its sailing rig. Handling the ship's full complement of 56 heavy 24-pounder cannon and 16 lighter carriage-mounted guns (Cederlund

2006:51) on a rolling deck required the mechanical advantage provided by blocks and tackles. Each of *Vasa*'s gun carriages was rigged with a pair of gun tackles used to run out the guns for firing, run them in for reloading, or to train them on a target.

Each gun tackle consisted of a single block and a double block that could be rigged in two configurations (Figures 8.2 and 8.3). The first configuration was to rig the tackles forward from the sides of the carriage to a pair of ringbolts on either side of the gunport. This readied the gun to be run out into the firing position. It could also be used to secure the gun at sea, drawing the carriage up against the ship's side with the barrel elevated until the muzzle seated snugly above the gunport. The second configuration involved rigging the tackles backward from the rear of the carriage to one of the ringbolts on the deck amidships. This prepared the gun to be hauled back from the gunport for loading, although this action was usually only necessary for loading the first shot. Normally, the recoil would shove the carriage back into the ship as far as the breeching would allow, leaving the gun ready for reloading. The gun tackle would then be used to haul against the breechings and thereby secure the cannon during the reloading process. Then the tackles were rigged forward again and the gun run out into firing position. The tackles were then slacked off or unhooked from the carriage just before firing to allow the breechings to govern the recoil and protect the tackle blocks from the shock. When aiming the cannon, the tackles could also be rigged to the ringbolts on the deck fore and aft of the gun position to train the gun side-to-side. Although this practice was common in later eras, it could be somewhat problematic when firing *Vasa*'s guns. In the 18th century, gun carriages were often fitted with four tackles. Two could be used to train the carriage side-to-side while another pair held the carriage up against the gunport. To control *Vasa*'s guns while training them side-to-side with the tackles would require using one to pivot the carriage and the other to hold it at the gunport. This may have in fact been the method used aboard *Vasa*, but leveraging the rear of the carriage sideways using the long handspikes found throughout the ship was certainly a more efficient way of shifting the carriage—especially on a crowded gundeck where rigging tackles to ringbolts just two or three meters away involves getting under the feet of the neighboring gun crews.

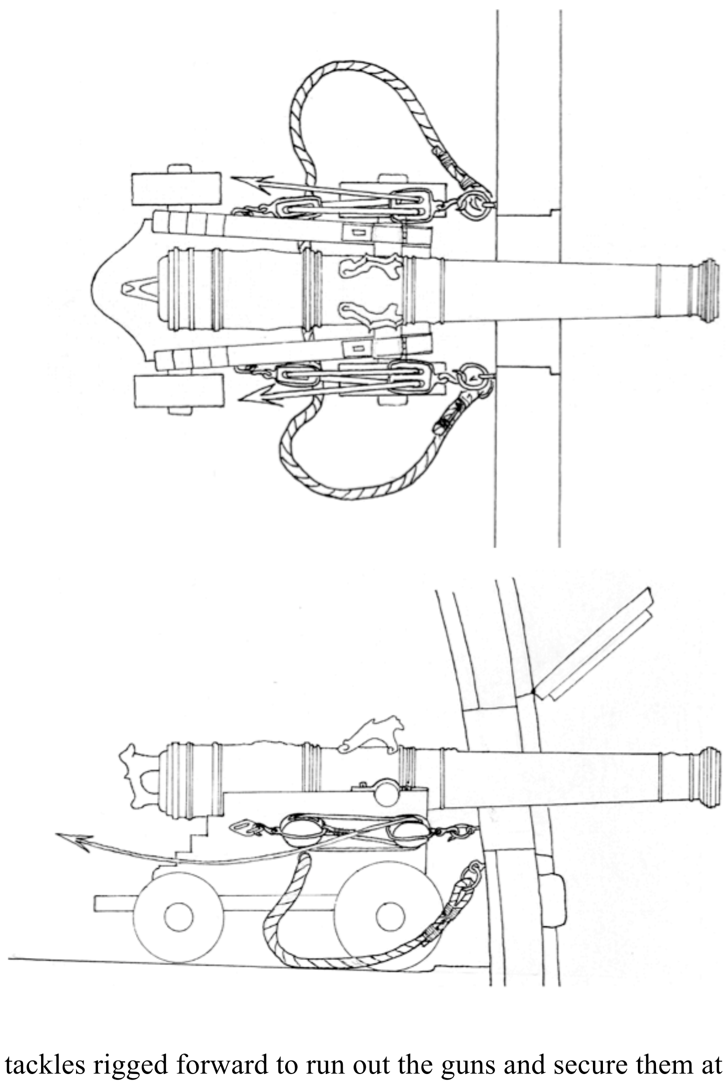


FIGURE 8.2. Gun tackles rigged forward to run out the guns and secure them at the gupnport. The tackles are unhooked before firing, allowing the gun carriage to recoil back into the ship until the breechings (the heavy cordage shown) draw tight and halt it (Drawings by Nathaniel Howe, 2011).

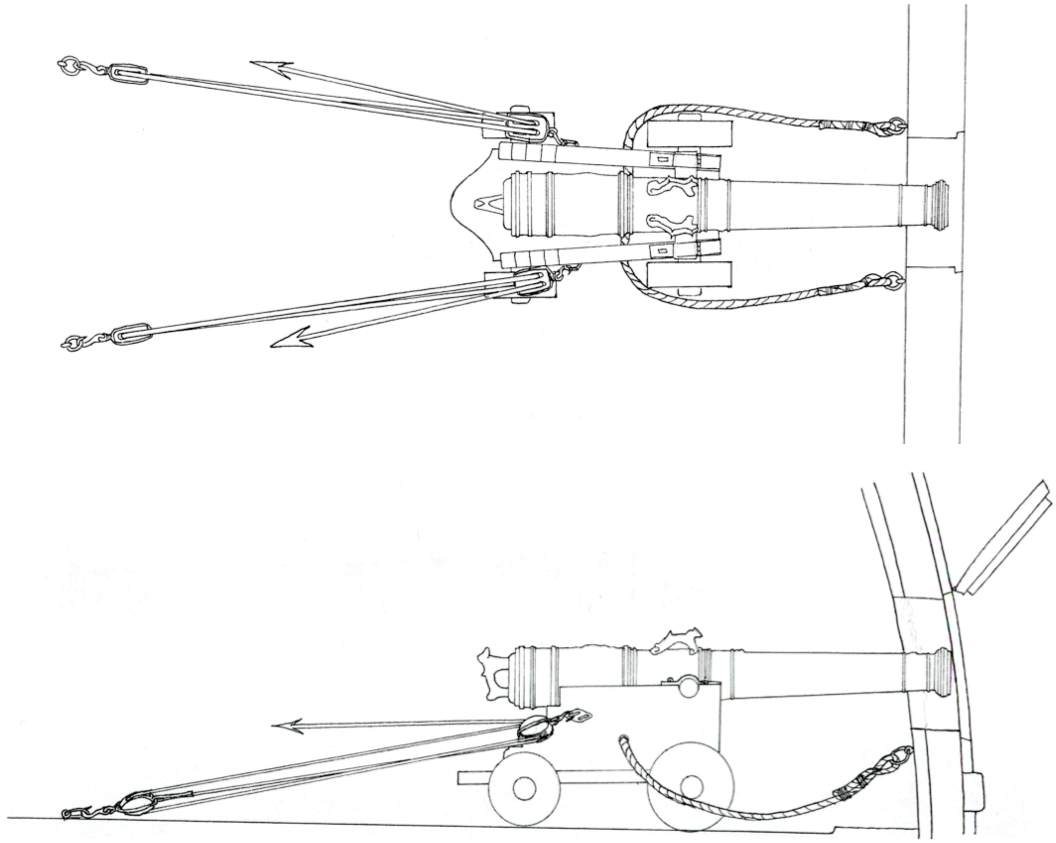


FIGURE 8.3. Gun tackles rigged inboard from the carriage to haul the guns in. The tackles are not pivoted on the carriage hooks, but actually shifted such that the single block is still in the inboard position, allowing the gun crews to stand inboard of the carriage and haul on the working ends of the tackles (Drawing by Nathaniel Howe, 2011).

When *Vasa* was recovered, 11 of the gun carriages found on the lower gundeck still had gun tackle blocks on or beside them. The cordage had decayed, but the blocks were still in close association with their gun carriages. Gun tackle blocks could also be identified from the excavation record with a high degree of certainty for five other carriages. From these 16 gun positions and their 32 gun tackles complete with all of their component blocks, it was possible to determine the identifying characteristics of the gun tackle blocks used onboard *Vasa*. Based on these characteristics, the tackle blocks belonging to almost 40 of the 56 heavy 24-pounder cannon positions could be identified.

The single blocks used in *Vasa*'s gun tackles were standard *sub-type 1* single blocks. Dimensions vary by 10 to 12mm, but all of these blocks are close to 230mm in length, 150mm wide, and 75mm thick with neatly chamfered edges. The interior dimensions were even more consistent with an average swallow of 32mm (+/- 2mm) leading over a sheave 28mm thick (+/- 5mm) and approximately 140mm in diameter (+/- 10mm). The majority of the block shells (86%) were made of oak, although a few (14%) were made of ash and all had a becket cavity chiseled out of the foot of the block to take the standing end of the tackle fall.

The double blocks were standard *sub-type 1* double blocks, made on the same pattern as the singles. Although much thicker (150mm) in order to house two sheaves, the other details were the same—averaging 230mm in length and 150mm wide with chamfered edges and 140mm-sheaves for 28-30mm cordage. None of the double blocks were becketed. This indicates that the standing end of the fall in each tackle was affixed to the single block. Every one of the double blocks was made of oak, indicating a clear preference in wood species.

Strangely, the gun tackle collection is far from complete despite the relative safety of most of the gun tackles down inside the hull during the ship's long years on the bottom. *Vasa* sailed with 71 gun carriages even though only 64 carriage-mounted guns had been loaded aboard. Eight of the 24-pounders had not yet been delivered, yet their carriages were ready and placed at the gunports (Cederlund 2006:51). Although all of the lighter guns had been delivered, one of the 1-pounders still awaited a carriage (Fred Hocker 2011, pers. comm.). The simple arithmetic for *Vasa* and its 71 gun carriages—each requiring a pair of gun tackles—shows a need for 284 blocks, breaking down to 142 single blocks and 142 double blocks. An examination of the size, shape, and find location of each of the blocks recovered from the gundecks, however, shows barely 180 that can be associated with the gun tackles. Thus 52 gun tackles, enough to fit out 26 gun carriages, are unaccounted for.

Some of the missing gun tackles could be explained by the eight 24-pounders that had not been delivered. Although there are carriages onboard for these eight guns, they were not necessarily fitted out with gun tackles. For example, the two stern chaser carriages on the orlop, known to have been empty, were found several meters from their gunports with only two blocks in the entire compartment that meet the design criteria for gun tackle blocks—well short of the eight blocks required (Cederlund 2006:397, 398). If the other six empty 24-pounder carriages also lacked gun tackles, this would account for roughly a quarter of the missing blocks.

Another possibility is that some of the gun tackles were removed when Treileben and Peckell retrieved the eight 3-pounders, six howitzers, and the two 1-pounders from the weather deck in the 1660s. Reportedly, these came up followed by their carriages (Cederlund 2006:88) and thus possibly the gun tackles as well. The recovery of 62 of *Vasa*'s 71 gun carriages in 1961, and the fact that one of the 1-pounders lacked a carriage, suggests that Treileben and Peckell managed to recover eight carriages. If the tackles came up with these carriages (a possible, but dubious hypothesis as the cordage and iron hooks probably decayed considerably in the 30 years since *Vasa* had sunk) the salvage efforts of the 1660s could account for eight pairs of gun tackles comprising 32 blocks—another quarter of the total quantity missing.

Yet, even when combined, these potential explanations account for only 32 tackles (64 blocks)—just 61% of those missing. Moreover, it is unlikely that all eight of the empty 24-pounder carriages lacked gun tackles. In fact, the stern chasers were probably the only ones. The other empty carriages were positioned at gunports, and while there is a definite shortage of gun tackle blocks throughout the upper and lower gundecks, their distribution does not seem to indicate that any of the carriages were entirely without tackle blocks. Similarly, the probability that Treileben and Peckell removed all the lighter gun carriages complete with their tackles is even more remote—particularly in light of the extensive damage done to the upper works prior to their arrival on the site (Cederlund 2006:84). The majority of the missing gun tackle blocks were most likely broken, removed by salvors, or simply eroded beyond recognition. Thus today, just 63% of the ship's requisite gun tackle blocks can be identified.

Blocks Stowed or Deposited Below

Deep in the hull lay another large group of blocks distinct from those directly employed in the sailing rig when *Vasa* sailed. Over 100 blocks were recovered from the orlop and hold, far below the heavy guns and expansive sailing rig where blocks and tackles were required. Protected under *Vasa*'s sturdy decks, these blocks were subject to far less damage or disturbance than any others found on board.

The majority of the blocks below decks were packed into five compartments—T3, T4, T5, H8, and H9. While a few appear to have been deposited during the sinking and salvaging processes, the vast majority were deliberately stowed below. The range of block types and associated object finds in each compartment provide clues as to why particular blocks were found in certain compartments. In some cases, these reasons are easier to deduce than others.

Compartment T3 held not only the largest group of blocks stowed below, but also the most readily recognizable assemblage. As soon as it was examined in 1961, the compartment was identified as *Vasa*'s sail locker. It contained six of the ship's sails, plus the mizzen bonnet, two small boat sails, and an assortment of spare shrouds, deadeyes, and a wide variety of specialized rigging blocks (Cederlund 2006:396). In total, there were 27 blocks of six types in compartment T3 (Figure 8.4). Many were still stropped or even rove, ready to be taken on deck and rigged. At least half of these blocks were spares, but the rest were rigging blocks with specific, assigned functions, standing by for use.

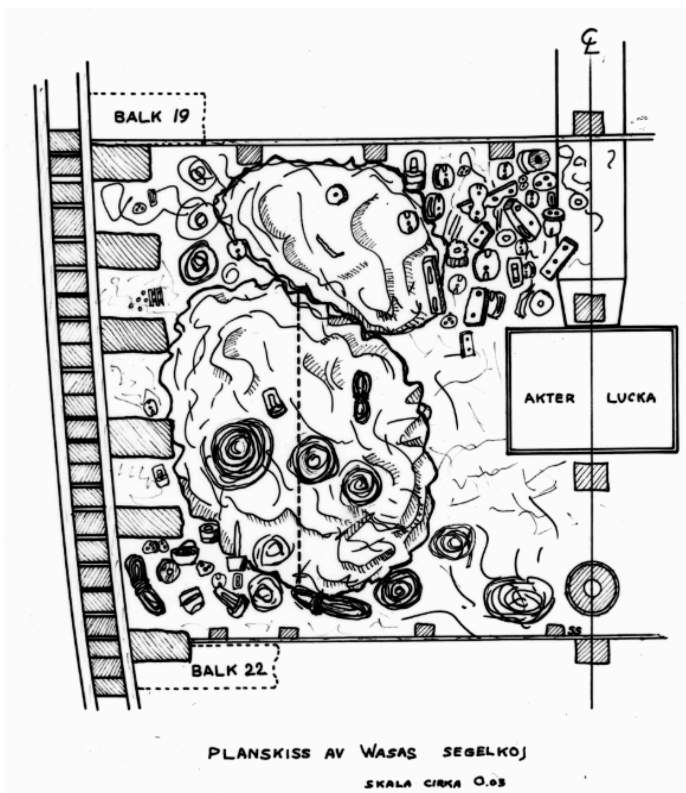


FIGURE 8.4. Excavation drawing of the sails and blocks found in compartment T3 (Drawing by Sam Svensson, courtesy of the Vasa Museum).

Unfortunately, attributing each of these blocks to a specific place in the rig reconstruction is virtually impossible. Contextual data for those still fitted to sails is not available while an examination of form yields no answers for the majority of the blocks in this space. Each of the generic single and double blocks, for instance, could have been rigged in a dozen different positions to fit out and set the six sails stowed in T3. Or, they could just as easily have been spares stowed in the sail locker. Some were likely not intended for *Vasa* at all, but belonged instead to *Vasa*'s ship's boat. Some of the specialty blocks in T3, however, are a little easier to place.

The nine dead blocks in T3 and T5 were most likely rigged in bowlines for controlling the windward edge of the square sails. Identifying to which sail they belonged is guesswork at best. The main course, the mizzen topsail, and the two topgallants in T3 all required two to six dead blocks each, depending on the configuration. Some ships of the period set up the bowline bridles with several dead blocks while others used a dead block and several thimbles or simply a couple of eye-splices (Hoving 2000:82 & Marquardt 1986:210) (Figure 8.5). Given the size of *Vasa*'s sails and the lack of thimbles in T3, *Vasa*'s bowline bridles were probably rigged with dead blocks. If so, the surviving dead blocks in T3 and T5 account for barely half of the 16 dead blocks required for the sails stowed below. The two largest dead blocks (Fnrs 18869 & 18984), with 51mm swallows, may have been for the main course. Another pair of dead blocks with 40mm swallows (Fnrs 18902 & 18983) was probably also used for the main course bowlines, or perhaps the main topgallant or mizzen topsail bowlines. The smaller dead blocks could have been components of these bowline bridles or maybe part of the bowlines for the smaller fore topgallant. Yet, ultimately, it is impossible to assert exactly where these individual blocks were rigged with any certainty.

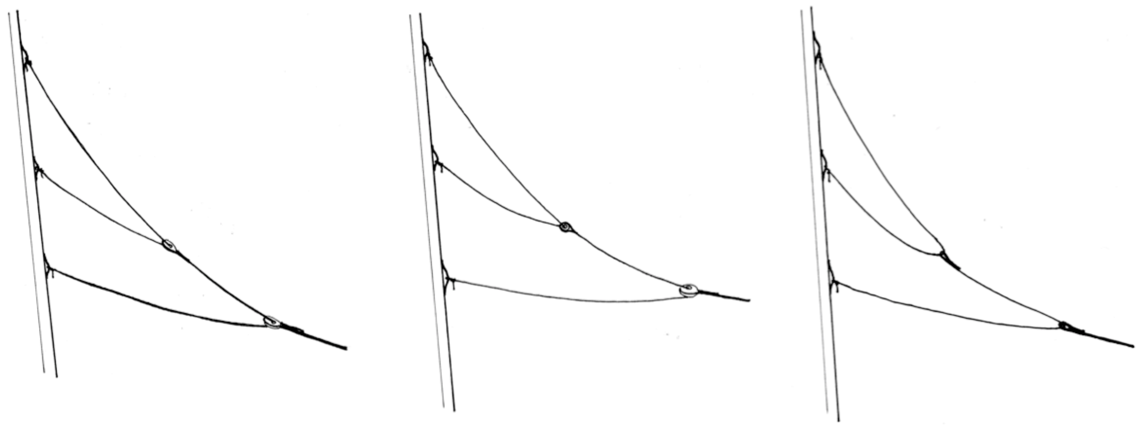


FIGURE 8.5. Common bowline bridle configurations with dead blocks, a dead block and thimble, and a pair of eye splices (Drawing by Nathaniel Howe, 2011).

Three of the four peculiar non-stropped long tackle blocks (*sub-type 4* double blocks) were in T3 as well (Figure 8.6). The fourth lay nearby in T5. All of these are made for 30mm cordage, but neither the archaeological context nor traditional Dutch rigging practices offer clues as to the specific purpose of these unusual blocks. The only comparable examples come from the 16th century wreck of the Basque whaler, *San Juan*, found on the bottom of Red Bay, Labrador, in Canada. Six non-stropped long tackle blocks, appearing in two sizes, were recovered from that wreck site. Although they are not shaped as gracefully as *Vasa*'s, they are remarkably similar in size and form (Figure 8.7). The Red Bay examples were found along the ship's main channels among the shrouds, and it has been suggested that they may have been employed in the mast tackles (Bradley 2007:IV-13 to IV-15).

FIGURE 8.6. One of *Vasa*'s unusual non-stropped long tackle blocks, Find Number 18982 (Photos courtesy of the Vasa Museum).

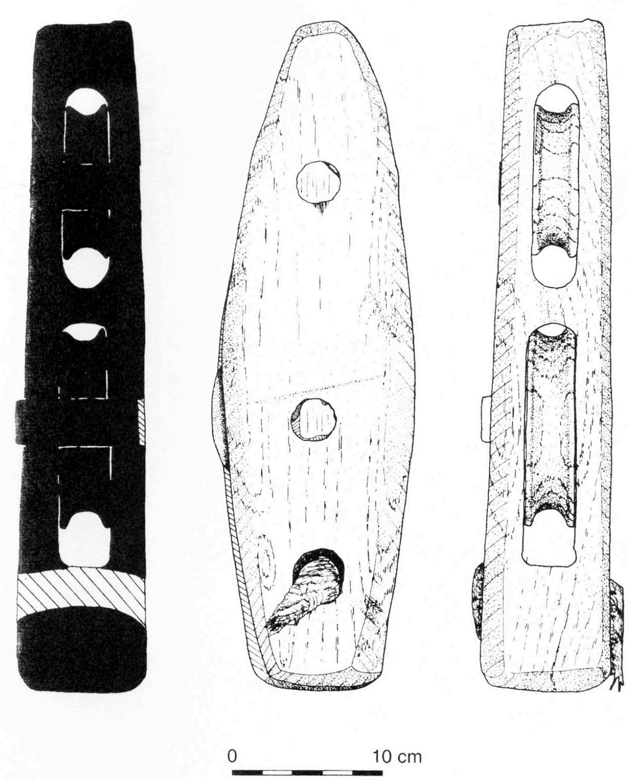


FIGURE 8.7. A non-stropped long tackle block from the Red Bay 24M site (Bradley 2007:Figure 17.1.25c).

Aboard *Vasa*, however, the non-stropped long tackle blocks must have served another purpose. None were found anywhere near the channels. The orlop was the only place these blocks were found. Moreover, their design is insufficient for service as mast tackle blocks on a ship of *Vasa*'s size. *Vasa* required particularly large, strong blocks in its mast tackles in order to assist the shrouds in a stiff wind or to hoist cargo or ordnance. Ultimately, the load capacity of the mast tackles was limited by the strength of its component blocks and cordage. Without a strop to reinforce the shell, these long tackle blocks were prone to splitting and their narrow, 32mm-swallows made these three-part tackles no more powerful than a gun tackle. By contrast, the broad, flat, *sub-type 4* single blocks, thought to be part of *Vasa*'s mast tackles (Stolt rigging reconstruction 1981), have swallows between 40mm and 50mm. If the non-stropped long tackle blocks were used as mast tackles, they could have done little more than tighten the shrouds' deadeye lanyards.

The intended function for the non-stropped long tackle blocks remains speculative. They may have been part of a vang or running backstay for the small boat's sprit rig, loading tackles for cargo, or spares taken into the Stockholm navy yard's chandlery from another ship or blockmaker. In fact, one of these blocks was found beside a set of shrouds taken from another ship, as evidenced by the knotted remains of ratlines. What is known is that these non-stropped long-tackle blocks are rare and atypical. In a period when rigging hardware design was becoming fairly consistent, this type is notably inconsistent with any known 17th or 18th century Dutch rigging practice. A parallel cannot be found in French or English rigging traditions either. Its only known corollary is in the wreckage of the Iberian whaler at Red Bay. The origin of this block design is impossible to trace. It may be an Iberian block form, an outdated Northern European form, or perhaps even a type used in small numbers aboard every ship that happened to evade the historical record. The use of ash instead of elm seems to indicate that it was most likely produced in a Scandinavian blockmaking shop, but probably not in the Stockholm navy yard. The stylistic and manufacturing details are inconsistent with the rest of *Vasa*'s rigging hardware. One of these blocks (Fnr 18982), for instance, has an extensive pattern of concentric rings on the face of its sheaves extending from the rim all the way to the axle hole. Those made in the little shop alongside the building ways in Stockholm are scored with only three or four rings near the rim.

A Dutch-style upper lift block was also recovered from compartment T3 and two more were found just outside in compartment T5 (Figure 8.8). These were spares. Dutch rigging practices called for only six of these blocks in the entire rig, employed in the lifts for the main and fore course yards and the crossjack yard (Hoving 2000:76; Winter 1967:*Tafel* 24). Topsail lifts were always rigged with common single blocks and the standing end simply becketed onto the foot of the block (Marquardt 1986:74). Given the importance of the course yards' specialized upper lift blocks and the high loads placed upon them, a ready stock of spares had to be kept on board.

FIGURE 8.8. One of the Dutch-style lift blocks recovered from compartment T3 (Photo courtesy of the Vasa Museum).

Another large group of blocks lay just outside the door to compartment T3 in the forward part of the orlop gunnery room (compartment T5). This group consisted of 32 blocks of various types including 22 single blocks, two dead blocks, three fiddle blocks, two upper lift blocks, a crane block, a double block, and the fourth non-stropped long tackle block. What specific purposes these blocks were intended to serve is impossible to determine. Despite being found in the gunnery room, only two could have been gun tackle blocks. Although there were many single blocks, only one was becketed and there was only one double block in the entire space. The blocks in T5, found along with a number of deadeyes and parrels, were clearly rigging stores.

There are two plausible scenarios explaining the presence of rigging stores in the gunnery room. The first scenario is that the rigging stores were deliberately deposited in the gunnery room beside the sail locker door, perhaps because the compartment needed to be put in order before stowing more gear or maybe in anticipation of needing to haul out several sails to be taken up on deck and bent on the spars. The second scenario is that this group of rigging blocks may have been flushed out of compartment T3 as the ship went down. Regardless of how these rigging blocks came to rest in the gunnery room amidst a heap of spare carriage trucks, rammers, and ladles, their composition clearly identifies them as part of the rigging store. Unfortunately, context and associated finds offer no clues as the designated purpose for each block. Most likely they were simply unassigned spares.

A lone single block was found in compartment T4 with a large collection of carpenter's tools. It may have been the carpenter's own block for handling awkward timbers, a block requiring modification, or perhaps it flushed through the sliding door into the compartment as *Vasa* flooded. The physical evidence offers no real clues.

Deeper in the ship lay another 44 blocks stowed in the hold. Blocks in this part of a warship are usually associated with powder and shot stores which invariably contain additional items pertaining to the ship's armament including extra rams, ladles, and spare gun tackle blocks—particularly if the gunnery officer wanted to protect his stock from the bosun's ever-present need for rigging hardware. Yet in *Vasa*'s case, the blocks stowed in the hold are distinctly *not* associated with the gunnery stores. Shot, canisters, ladles, and rams were primarily found in compartments H2 and H5. Smaller caches were also present in H1 and up on the orlop in compartment T5 (Cederlund 2006:371-378, 397-398). Yet, no blocks were found in H1 at all, only two blocks and an ash sheave were found in compartment H2, and just a few sheave fragments were recovered from the debris in H5. Instead, almost all of the blocks in *Vasa*'s hold were in the stern in compartments H8 and H9—at least 12 meters from the gunnery store in H5.

The blocks in H8 and H9 consist of 20 single blocks and eight double blocks and are certainly not spare gun tackle blocks. In addition to the fact that these blocks were not found in the vicinity of any other gunnery stores, the disproportionate ratio of single blocks to double blocks indicates that these were not intended to be paired up to form tackles. Moreover, only one of the single blocks is carved with a becket—one of the defining features of gun tackle blocks as defined by those found on the gundecks above.

The blocks in the aft portion of the hold are not gun tackle stores, but they are stored there for a very specific reason. Each and every one of the blocks in compartments H8 and H9 is broken, split, or defective in some way. Most split across the head and foot of the shell. One block has an axle that is too short (Fnr 14897). Another block (Fnr 15251) has a broken axle and a split shell. Yet another (Fnr 16735) has an axle but no sheave, suggesting it split and fell out of the block. Perhaps the most interesting example is a block (Fnr 15375) with a pronounced notch in the shell from abrasion indicating that the fall jumped the sheave and wore a gouge out of the cheek. Every one of the blocks in compartments H8 and H9 was stowed there because it was defective. This space served as *Vasa*'s spare parts locker where blocks that were broken while fitting out and rigging the ship were stashed for later salvage or repair. Five more broken blocks, including four singles and a double, were found in compartment H6. A battered dead block and five single blocks with broken shells or axles were recovered from H7.

The lack of a dedicated gun tackle store anywhere on the ship is intriguing. On the orlop, all of the major block stowage areas contained obvious rigging blocks among possible gun tackle blocks, while in the hold all the blocks were broken. Although it seems strange that a dedicated gun tackle store was not found anywhere on the ship, perhaps it was simply unnecessary. The standard *sub-type 1* single blocks found on both decks are appropriate for use either in the rigging or in the gun tackles, suggesting that Swedish naval policy may have been applying the concepts of standardization and interchangeability that were dominating Swedish weaponry design in other areas, including gun carriages and gun tackles. Consequently, a stock of reserve blocks could provide for either gunnery or rigging. The lack of beckets in the spares is also informative, indicating that it was the rigger, not the block-maker, who was responsible for cutting the becket cavity into the foot of the block. As the rigger chose exactly where and how each block was to be rigged, and carving a becket takes only a minute or two with a sharp knife or chisel, this is entirely logical.

This conclusion is also supported by the writings of Nicolaas Witsen, the Dutch East India Company's most prolific writer on matters of shipbuilding and outfitting. In his comprehensive manuscript on the topic, *Aeloude en hedendaegsche scheepsbouw en bestier* (Witsen 1690), he includes detailed lists of the equipment and spares to be loaded on board for long voyages. In his catalogue of military equipment, *kryghs-tuigh*, he lists edged weapons, small arms, powder, shot, and every item required for loading and firing the cannon including spare tackle hooks (*talie-haaks*). The one item missing from the list is additional tackle blocks (Witsen 1690:350). According to Witsen, these were not considered to be part of the gunner's store. Instead, Witsen lists spare blocks in its own category, *losse block-werk*. This list includes spares for the entire ship consisting of every block-type used on board. Interestingly, none of these blocks are listed as spare gun tackle blocks (Witsen 1690:352), implying that the single blocks in the rigging store were available for any purpose required.

Blocks of the Rig

The second largest group of blocks recovered from the wreck site consists of those that were actually rigged and functioning on the 10th of August 1628 when *Vasa* foundered. A warship of *Vasa*'s sail plan typically carried over 300 blocks in the rig (Figure i.1), the vast majority being single blocks. Yet, out of the total 412 blocks recovered, fewer than 90 can be directly associated with the rigging at the time the ship sank. That amounts to less than a third of *Vasa*'s rigging blocks.

Considering the fact that the entire rig above the tops was cut away shortly after the sinking and the remainder was largely destroyed during subsequent salvage attempts, a 70% loss is entirely within reason. The rigging blocks that did survive were those that fell onto the upper gundeck or into the mud around the ship. These include virtually every block type found on the site. For continuity, the discussion below follows roughly the same organization used in the earlier discussion of squaresail running rigging.

Controlling the Yard: Halyard, Lift, Brace, and Spritsail Garnet Blocks

Three basic rigging systems were required to control *Vasa*'s yards. Each required at least seven specialized blocks, particularly for the heavy course yards. When *Vasa* sank, 27 blocks were actively managing the three squaresail yards that had sails set—the main topsail, fore topsail, and fore course. With all ten sails set (a rare if ever practiced occurrence), more than four times that number would come under strain. Some of the blocks rigged in these three principal systems for controlling the yards are reasonably easy to identify among those recovered with *Vasa*.

Ram's Head Blocks: The most readily identifiable rigging blocks found aboard *Vasa* are the two enormous ram's head blocks. These are so distinctive and sufficiently undisturbed that the identity, function, and placement of these blocks in *Vasa*'s rig are virtually incontestable. Aboard Dutch-rigged ships, the ram's head block was rigged as part of the main and fore course halyards. These massive yards, loaded down with a ton or more of cordage and sailcloth, could only be hoisted aloft using tremendous mechanical advantage. The ram's head block provided that advantage by forming the upper end of a powerful six-part tackle rove to the knighthead. The fourth sheave in the ram's head block was not for reeving the tackle, but for carrying the heavier tye ropes. Its primary function was to balance the tension in the two legs of the tye rope as the yard was braced to port or starboard. Consequently, it probably never actually turned a full revolution. Yet, it was far from insignificant. The stout dimensions of these sheaves in the two ram's head blocks attest to the impressive size of the cordage and the heavy strain on these sheaves. In fact, a short length of the tye rope 70mm in diameter was found in the fore-course halyard block (Fnr 08008).

The largest of *Vasa*'s two ram's head blocks (Fnr 09843), found on the upper gundeck just forward and to port of the mainmast, lay barely a meter from its original position in the rig (Figure 8.9). The block measures 1015mm in length and weighs in at 64.5 kg without its iron sheaves (another 50kg themselves), making it the largest block found in association with *Vasa*. The second and slightly smaller ram's head block (Fnr 08008) was also found almost immediately under its original location, lying on the upper gundeck beside the foremast.

FIGURE 8.9. Ram's head block 09843 from the main-course halyard (Photo courtesy of the Vasa Museum).

Both ram's head blocks are essentially identical in form and detailing. The principal differences between *Vasa*'s two ram's head blocks are in size and material. The larger block for the main-course yard is cut from a solid block of ash while the slightly smaller fore-course block (Figure 8.10) is made of oak. Both are so large as to require an entire section of a tree trunk with the core running almost straight up through the middle of the block. The fact that the two ram's head blocks—possibly the most important blocks on board—are made from different wood species raises an intriguing question about the interchangeability of wood species in blockmaking. Initially, it seems to suggest that the builders considered oak and ash to be almost entirely equal. Yet, the presence of deep wear marks in the fore-course ram's head block presents another interpretation.

FIGURE 8.10. Ram's head block Fnr 08008 for raising the fore course yard (Photos courtesy of the Vasa Museum).

It is thought that *Vasa*'s foremast might have been obtained from an older ship in the fleet where it had been rigged as a mainmast (Fred Hocker 2006, pers. comm.). The deep, circular wear marks in the sheave mortises of the fore-course ram's head block—to be expected in a well-used, multi-sheaved, tackle block with iron sheaves—may indicate that the block, and perhaps even the fore-course yard, was also transferred to *Vasa* along with the mast. If so, the difference in wood species might not reflect the professional views of the Stockholm navy yard's blockmakers at all. Instead, it may simply be the product of another craftsman's decision while producing for another ship years earlier.

Lift Blocks: To keep *Vasa*'s yards level, lifts were fitted between the masthead and the ends of the yard (Figure 8.11). The main and fore-course lifts were doubled for greater mechanical advantage and fitted with specialized upper and lower Dutch-style lift blocks. The topsail yard lifts consisted of more conventional single blocks, doubled only when the topgallants were struck.

A total of seven Dutch-style upper lift blocks were found in association with *Vasa*. These were slightly modified from Dutch design, lacking the concave curves of the two vase-neck ends for a more bulbous and thus generally almond-shaped form. As each of *Vasa*'s two course yards and possibly the mizzen's crossjack yard required a pair of these blocks, only six are to be expected on the ship. Four were found below the rig on the upper gundeck and in the mud. The other three lift blocks were found grouped together amidst the rigging stores on the port side of the orlop. These all have slightly smaller swallows (3-8mm narrower) One of them (Fnr 20000), is very crudely made and certainly not the work of the navy yard blockmaking shop. Moreover, it is made of birch instead of ash and its edges are chamfered rather than rounded.

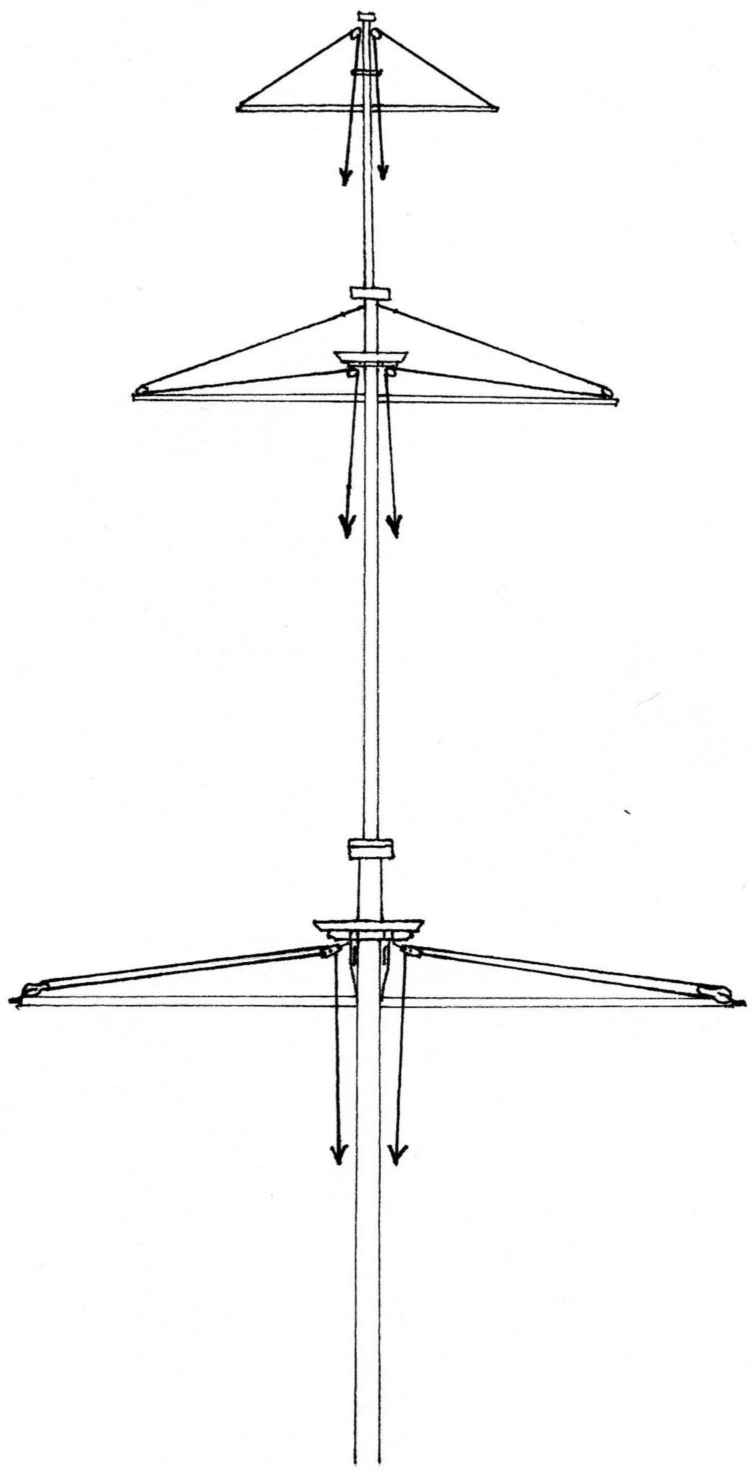


FIGURE 8.11. Yard lift diagram. Only the course yard lifts use specialized block types. The topsail and topgallant lifts are rigged with common single blocks (Drawing by Nathaniel Howe, 2011).

The four lift blocks found on the exposed upper gundeck or in the mud surrounding the ship were slightly larger and can be placed in the rig with reasonable certainty. Of the two that lay in the mud, one was directly in front of the ship (Fnr 20527) while the other lay beside the port bow (Fnr 21454). Those on the upper gundeck deck were positioned with one just to starboard of the mainmast (Fnr 03741) and the other just forward of the capstan (Fnr 04348). These four are all somewhat larger than those that were in the rigging store and are actually better preserved. These average 427mm in length, or about 60mm longer than the spares, suggesting that perhaps the spares were for another purpose. A 1651 model of the Dutch East Indiaman *Prins Willem* housed in the Dutch National Museum in Amsterdam does show lift blocks employed in the topsail lifts; however, that was abnormal for the period. Moreover, as *Vasa*'s topsails were set when the ship sank, the topsail lifts were almost certainly rigged, not stowed (Cederlund 2006:53).

The find locations of the four lift blocks found on deck or outside the ship make it possible to infer what their original functions might have been. The one beside the port bow (Fnr 21454) and the one in front of the ship (Fnr 20527) were probably the port and starboard lift blocks for the fore-course yard. Their arrangement diagonally across the bow even suggests they may have fallen when the yard—still braced to port—fell from the mast, trailing the lifts after it and tumbling them over the port bow (Figure 8.12). Indeed, the single lift pendants could easily have parted sooner than the doubled falls, leaving the blocks attached to the yard rather than the foretop. Adding credibility to this interpretation is the presence of a combined topsail-sheet and lift block (the other end of the lift tackle) found on the port side just five meters further aft—almost exactly the distance between the blocks in the fore-course lift tackle. This suggests that the upper and lower lift blocks were still reeved as the yard went down, the upper lift block with its broken pendant trailing in the current.

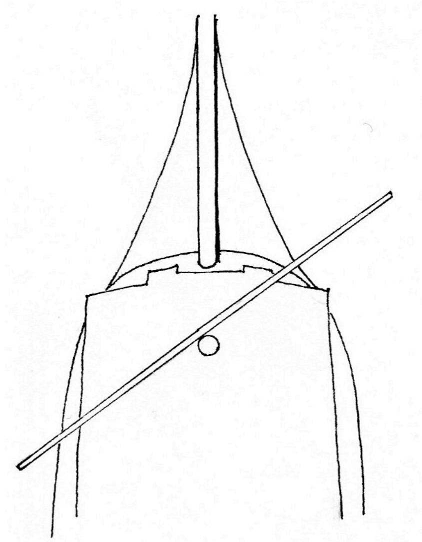


FIGURE 8.12. Plan view of bow showing fore course yard braced hard to port where it and its lift blocks fell (Drawing by Nathaniel Howe, 2011).

The other two upper lift blocks found on the deck are from the port and starboard lifts for the main course yard. The starboard lift block (Fnr 03741) was found beside the mainmast directly below its position in the rig. Its pendant to the main top therefore held longer than the fall. The other lift block on the upper deck (Fnr 04348) found just forward of the capstan may have been carried forward by the current or been moved during the salvage operations.

The combined topsail-sheet and lift blocks at the lower end of the lift tackles were highly distinctive on Dutch-rigged ships (Figure 8.13). While English ships stropped two single blocks together and the French tended to use a fiddle block for this purpose, the Dutch developed a special dual-function block with two sheaves set 90° to each other along the longitudinal axis.

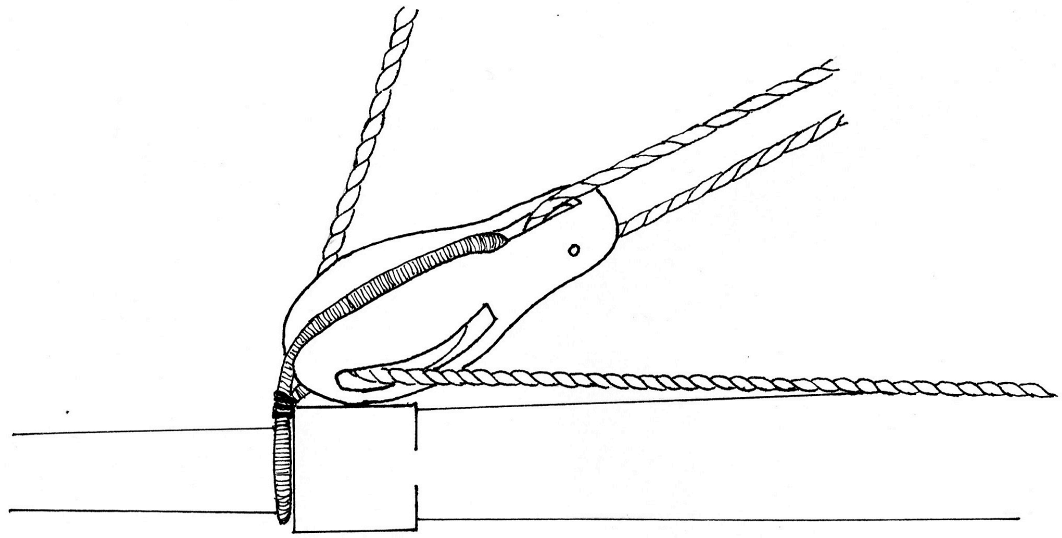


FIGURE 8.13. A Dutch combined topsail sheet and lift block rigged in place (Drawing by Nathaniel Howe, 2011).

Since these specialized combined sheet and lift blocks were only used in the lifts for the course yards, *Vasa* was fitted with just four of these blocks. When the ship was recovered, however, only one was found (Figure 8.14). What happened to the others is impossible to say. They may have fallen into the mud well outboard of the ship and been missed during the salvage work in the late 1950s. Another possibility is that the blocks may have disappeared with the yards (also missing by the time of the salvage) as they were mounted with a very heavy strop and could be expected to outlast the fall and endure as long as any cordage in the rig.

FIGURE 8.14. *Vasa*'s combined topsail sheet and lift block, Find Number 23455 (Photo courtesy of the Vasa Museum).

The sole topsail-sheet and lift block recovered from the *Vasa* wreck site (Fnr 23455) was found in the mud beside the port bow approximately abeam of the weather-deck capstan. This location is about halfway between the main and foremasts, making it difficult to determine whether it fell from the fore-course yard or the main-course yard. The presence of an upper lift block (Fnr 21454) lying in the mud just a few meters forward of this lone topsail-sheet and lift block, the fact that the ship was on a port tack with the yards braced around to that side when it sank suggest that the topsail-sheet and lift block was rigged on the port end of the fore-course yard. At some point the parrels and ties must have parted, allowing the yard to fall to the deck. If the port braces were still attached, this would have pulled the upper and lower lift blocks on the port side of the fore course toward their final resting place.

Brace blocks: It is impossible to identify any brace blocks in the *Vasa* collection. These were among the most exposed to destruction from salvage attempts and, according to contemporary etchings and paintings, these blocks were simple, *sub-type 1* single blocks virtually indistinguishable from the hundreds of other single blocks in the rig (Anderson 1927:148; Hoving 2000:30-54, 78). The brace blocks for the course yards were probably a little larger to absorb the strain and may be possible to identify. A 300mm *sub-type 1* single block (Fnr 23358) found in the mud on the port side a few meters abaft the foremast could be a candidate for the port fore-course brace block, but other there is no clear indication.

Spritsail Garnet: A pair of fiddle blocks (Fnrs 23140 and 20795) (Figure 8.15) found in the mud immediately in front of the ship probably come from the spritsail garnets. These tackles, rigged between the forestay and the spritsail yard, functioned as both lifts and braces for the yard (although the yard also had dedicated braces) (See Figure 1.2). A variety of arrangements were used in early 17th-century spritsail garnets and only a handful of large ships seem to have employed tackles rigged with fiddle blocks, but it is the only known use for a fiddle block this far forward in the rig (Anderson 1927:219).

The pair of fiddle blocks was stropped to the forestay, just abaft and above the spritsail yard. A single block was fitted approximately half way between the middle and the end of the spritsail yard. This was done on both port and starboard. Each spritsail garnet had its standing end becketed to a single block. The fall ran up to the lower sheave in the fiddle block, back through the single block, up to the upper sheave of the fiddle block, and then down to the beak head to be belayed (Anderson 1927:219). This formed a three-part tackle capable of raising the leeward side of the heavy, and often soaking wet, spritsail yard up to an angle as high as 50 degrees. Functionally, this formed the spritsail into a sort of mock lateen sail that could generate extra forward driving energy when sailing to windward.

FIGURE 8.15. One of *Vasa*'s fiddle blocks found in the mud off the bow (Photo courtesy of the Vasa Museum).

Controlling the Sailcloth: Sheet, Clew, Buntline, Martnet, and Bowline Blocks

The five major rigging systems controlling the sailcloth each involved a series of blocks. Although some of these were highly specialized, most were common single blocks. Dutch rigging practices, in particular, used ordinary single blocks for every capacity except for a few of the sheet blocks. The blocks recovered with *Vasa* that may have been rigged in these systems are discussed below in order of fundamental importance to the operation of the sail.

Sheets: In the entire *Vasa* block collection, only one block can be positively identified as a sheet block. This is the combined topsail sheet and lift block discussed above (Fnr 23455) that was most likely fitted to the fore-course yard. The sheet passed around the larger sheave, measuring 370mm in diameter and 77mm thick—one of the thickest sheaves in any block found on the ship. The sheet itself—one of the heaviest lines in the running rig—was probably close to 70mm in diameter in order to restrain the massive foretopsail. Three more of these specialized sheet blocks were fitted on the course yards, but those have not survived.

The sheet blocks for the fore course might also be possible to identify. Two heavy, thick-walled, *sub-type 10* single blocks (Fnrs 00688 & 23504) were recovered from the mud on either side of the bow, roughly in line with the yard if it were braced to port as it was when *Vasa* foundered (Figure 8.16). Although heavier than the other *Vasa* blocks, they are stylistically similar, featuring all wooden construction with carefully rounded edges. These two blocks are a matching pair, measuring 310mm in length and made to carry cordage of up to 40mm in diameter—approximately the proper size for the fore-course sheet, if doubled back through a block, and matching the sheaved sheet fairleads in the bulwarks. The thick cheeks strengthened the block against splitting if it were to strike hard against the hull when the sail is back-winded for tacking or when braced hard over.

FIGURE 8.16. The thick-walled *sub-type 10* single blocks that may have been the fore course sheet blocks (Photos Courtesy of the Vasa Museum).

A pair of large *sub-type 1* single blocks (Fnrs 19904 & 19906) found on the orlop in compartment T3 near the main course could be the main-course sheet blocks. Stylistically, they are very different from the two aforementioned blocks that might be the fore-course sheet blocks, yet neither form is more reliably attributed to service as a sheet block than the other. The two blocks in T3 are the only ones in that space that are large enough for the task (50mm swallows) and it stands to reason that the course sheets might have been stowed below with the sail.

The other sheet blocks, however, are either known to have been lost or are impossible to identify. The topgallant sheet blocks were salvaged with the upper rig in 1628. Although the topgallants were struck and stowed below, Dutch rigging practice was to keep the topgallant sheet blocks aloft, re-rigging them as the topsail yard’s lower lift blocks (Marquardt 1986:91). The mizzenmast and its blocks were never found, but parts of the mizzen top fell on deck around the mast, attesting that it stood for at least a decade or more after the sinking. At least some of the blocks found on the deck are probably from the mizzen course (lateen) and mizzen topsail. But none of these blocks were specialized types distinguishable from other blocks in the same find area. The sheet blocks for the spritsail and sprit topsail were probably stowed in compartment T3 with those sails, but contemporary artistic sources indicate that these were essentially common single blocks indistinguishable from the others stowed there. Similarly, the quarter blocks, which were part of the topsail and topgallant sheet systems, were also common single blocks. One of these blocks was fitted just to either side of the middle of each topsail and course yard. These redirected the sheet coming up from the deck out toward the sheet block at the end of the yard, allowing the yards to be braced from side to side without slackening or tensioning the sheets. Those used on the course yards have not been possible to identify based on form or distribution as these would have been common *sub-type 1* or *sub-type 2* single blocks. Only the large swallow diameter—matching the combined topsail-sheet-and-lift blocks—could single them out.

Unfortunately, because the majority of the blocks involved in controlling the sailcloth were common single blocks, very few can be positively identified. The quarter blocks, clew blocks, and buntline blocks on a Dutch-rigged ship were all common single blocks—the most universal block type employed aboard ships (Hoving 2000:30-51, 80). *Vasa*'s were all *sub-type 1* or *sub-type 2* single blocks. Neither type was scarce on the wreck. Consequently, determining the original position of individual single blocks in the rig is virtually impossible. There are simply too many valid possibilities for each one.

The blocks rigged in the clews and buntlines, therefore, can only be discussed in generalities.

Clews: On a Dutch-rigged 17th-century warship, each of the clew systems that drew the corners of the sail up to the yard for furling was rigged with two blocks (Anderson 1927:157). The standing end of the clew was affixed approximately one-third of the distance outboard from the middle of the yard. It ran down from the yard to the first block, fitted to the clew of the sail. Then it ran back up to another block on the yard near the standing end. From there, the fall ran down to the deck, the topsail clews usually passing through a lead block on the way down. The first block at the clew of the sail was the clew block proper. The clew block was typically somewhat small as it only had to bear the weight of the sail for a short time and part of that load was shared with the buntline blocks. The second clew block was usually no more distinctive than the first. None of *Vasa*'s smaller single blocks found on the upper gundeck, on the orlop, or in the mud can be even cautiously identified as a clew block. Unlike the distinctively acorn-shaped English clew blocks found on *Mary Rose* (Marsden 2009:264), the form and distribution of the single blocks used for *Vasa*'s clews simply do not stand out.

Buntlines: Similarly, the buntline blocks are not distinguishable from the rest of the common single blocks rigged on *Vasa* either. The buntlines were used to gather up the belly of the sail from the forward side and raise it to the yard for furling (Fig. Howe-76). The standing end was tied off to a cringle at the foot of the sail and the fall ran up the front of the sail to a block hung on the yard and then to a block secured on a stay just above the yard. From there it was taken aft to the deck for handling (Anderson 1927:172). Each buntline therefore required two blocks. *Vasa*'s main- and fore-courses were fitted with five buntlines each (Hocker, personal communication). The lighter topgallants could be gathered up by hand. Since the buntline blocks are indistinguishable from the multitude of other small single blocks found in association with *Vasa*, none can be positively identified.

Martnets: The martnets were also used to gather up the sail for furling. These lines were attached to the leeches of the sail, bringing the leech inboard as they were drawn up. To spread the load, the martnets were attached to the sail with a set of crows-feet, both forward and abaft the sail. Each of the crows-feet was united with a deadeye that hung on a pendant running up over the yard, through the lower sheave of a sister block, and then down to the other martnet deadeye. The common pendant passing through the sister block allowed the martnets to shift and balance tension as the sail billowed forward.

To draw in the martnet, a fall was secured to the masthead that ran out to the upper sheave in the sister block, back to a single block hanging on a pendant from the masthead, and then down to the deck. When hauled in, the sister block drew the martnets upward and inward, gathering the leech under the yard. Martnets were eventually replaced by leech-lines around 1650, but in *Vasa*'s period they remained standard (Anderson 1927:186). Unfortunately, none of the indicative sister blocks were found. The martnet deadeyes may lie among those that fell from the topmast shrouds, but they cannot be distinguished. As the single block on the pendant was affixed to the topmast, it was most likely salvaged with the upper rig. To date, no elements of the martnets can be identified.

Bowlines: Evidence of *Vasa*'s bowlines, however, does remain. Each of *Vasa*'s squaresails was rigged with a pair of bowlines to alternately hold the luff, or windward edge of the sail, forward in the breeze and prevent it from back-winding. The bowlines were attached to the sail with a set of bridles to distribute tension and preserve the shape of the sail. These led to a single line carried forward to a block secured on another mast or stay and then down to the deck. Early 17th century Dutch-rigged bowlines employed two types of blocks—dead blocks and snatch blocks. The dead blocks were rigged to connect and balance tension between the individual legs in the bridles. Some ships of the period set up the bowline bridles with several dead blocks, others used a dead block and several thimbles, and some were simply rigged with a couple of eye-splices (Anderson 1927:167).

In addition to the nine dead blocks stowed on the orlop, eight more were found on deck and in the mud around the ship (Figure 8.17). These may have been rigged as *Vasa*'s bowlines at the time of the sinking. Three are on the upper gundeck, three more are in the mud around the ship, and two seem to have fallen through the hatches amidships. One came to rest on the lower gundeck (Fnr 11658), and the other on the orlop (Fnr 18880). It is difficult to relate any of these dead blocks to a particular sail. A sizable example (Fnr 07759) found beside the foremast on the upper gundeck probably fell directly from the fore-course's port bowlines. Just inboard and below it, a large dead block abaft the foremast on the lower gundeck (Fnr 11658) is also probably from the fore-course's port bowlines. Both are carved with 35mm swallows—notably smaller than the 51mm swallows of the two large dead blocks stowed with the main course. It is possible that the dead block that the dead block that fell down the hatches to the orlop, just five meters forward and to port of the mainmast (Fnr 18880), may have been from the main topsail bowlines. This is particularly likely if the bowlines were cut or cast off as the topsail was salvaged following the sinking. The bowline bridles were approximately four meters underwater once the ship had settled on the bottom.

FIGURE 8.17. A small dead block (Fnr 04729), possibly from the bowline bridles (Photos courtesy of the Vasa Museum).

Two of the three tiny 85mm dead blocks were found at the stern, one on deck (Fnr 04729) and one in the mud (Fnr 00405). The third (Fnr 23257) was near the port bow. These are too small to be rigged in the bowlines of any of the squaresails set at the time of the sinking. Furthermore, there is no reason for bowline blocks at the stern as long as the mizzen topsail was struck below. Most likely, these tiny dead blocks served another purpose, perhaps as part of the mizzen brails.

During the 17th century, snatch blocks were only used in the main-course bowlines (Anderson 1927:166). These bowlines ran forward from the sail to a snatch block at the base of the foremast and then secured there (Figure 8.18). A large snatch block (Fnr 08692) was found at precisely that location, confirming that *Vasa* was rigged in this manner.

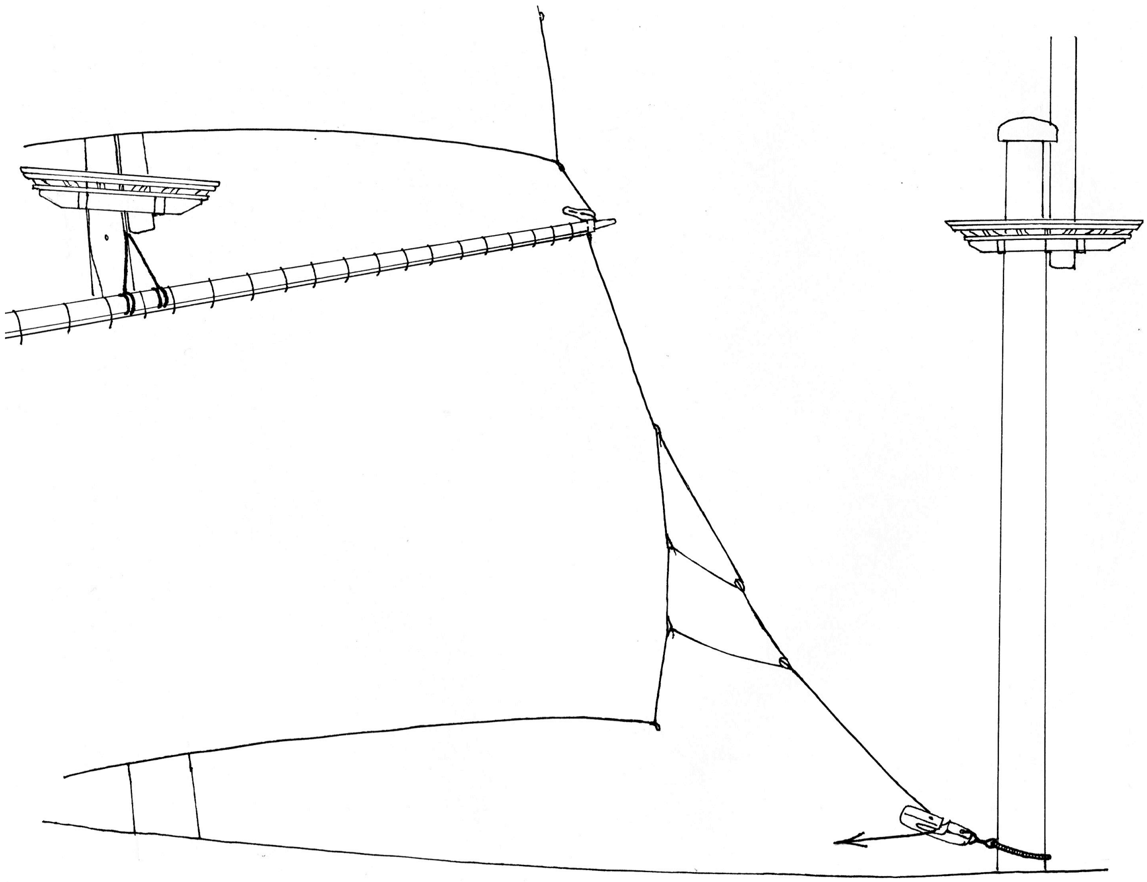


FIGURE 8.18. Main course bowline snatch block rigged (Drawing by Nathaniel Howe, 2011).

The need for this specialized block arose when tacking. During this operation the windward bowline had to be slacked off and the leeward one drawn taught as the yard braced around and the ship turned across the wind. To get the sail to fill on the new tack, it was imperative that the bowline on the new windward side be drawn tight as quickly as possible. The main-course bowlines, however, were extraordinarily long in order to accommodate the broad arc of the yard as it braced around. This required the crew to pass great lengths of line through the bowline blocks very rapidly. It was hard and cumbersome work prone to kinking and snagging that could easily ruin the whole maneuver. To alleviate slow tacking times and the danger of fouling the bowlines, a snatch block was placed at the base of the foremast. This allowed the crew to simply snatch the windward bowline out of the block and let it run free. They could then drop the new windward bowline into the block and draw it taught quickly without having to reeve it through from the bitter end (Figure 8.19).

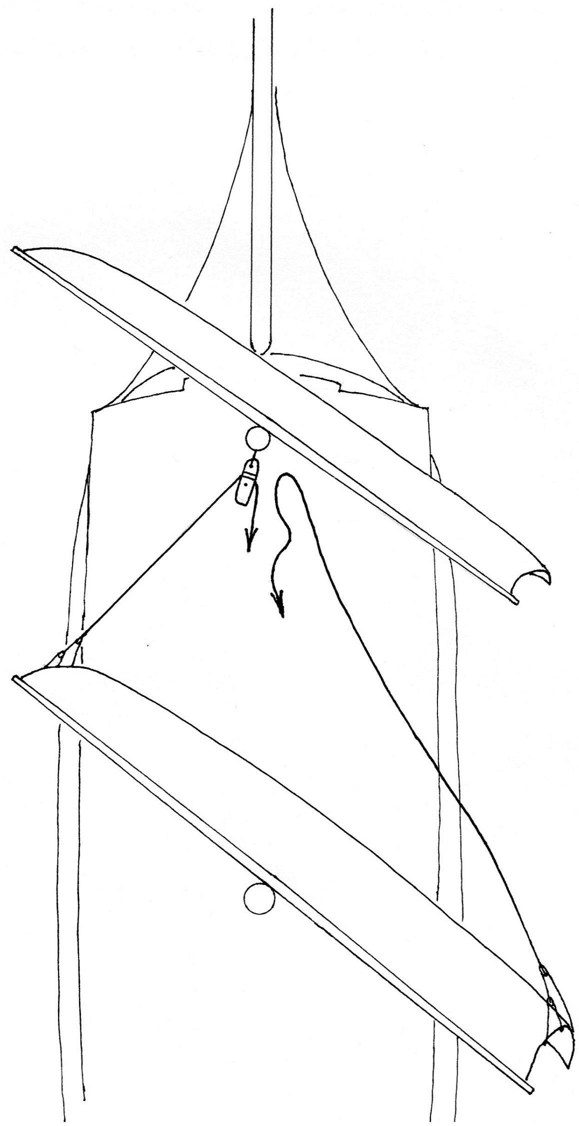


FIGURE 8.19. The main course bowlines run to the snatch block at the base of the foremast and the windward bowline rove through and held under tension (Drawing by Nathaniel Howe, 2011).

Vasa's main-course bowline snatch block (Fnr 08692) is 832mm long and cut with a 72mm swallow (Figure 8.20). It has an ash shell carved in the same style as many other specialty blocks from *Vasa* with chunky dimensions, chamfered edges, and a wooden axle pin. An ordinary strop could not be used without blocking the fall's entry into the sheave mortise so it was secured to the mast by a collar passed through a hole bored in the head of the block. The lack of an encompassing strop to distribute the load made snatch blocks especially prone to breakage. Sudden slackening of the bowlines would also drop the block on the deck with considerable force. Consequently, the shell is over-built to bear the strain and abuse it could be expected to undergo.

FIGURE 8.20. *Vasa*'s main course bowline snatch block (Photos courtesy of the Vasa Museum).

A large number of other single blocks from the rigging were scattered about the decks and on the harbor bottom. Where they were rigged will never be known. As one of the few truly standardized pieces of equipment onboard, perhaps it does not ultimately matter. They were intended to be interchangeable. Most are common *sub-type 1* single blocks with elliptical shells and chamfered edges, virtually identical to the gun tackle blocks. The main distinguishing feature is the lack of becket cavities (although a few of those in the rig were certainly becketed too). Among the *sub-type 1* single blocks of the rig there is a higher preponderance of ash block shells and far greater variability in dimensions, but little else differs between them. Seventeen *sub-type 1* single blocks were found on the upper gundeck and 28 more in the mud surrounding the ship. These appear in at least ten distinct sizes ranging from 110mm on up to 500mm and are built to carry falls of five different dimensions between 15mm and 85mm in diameter.

Eighteen *sub-type 2* single blocks with an oval shell, flattened ends, and rounded edges were found in the mud or on the upper gundeck as well, plus one more that seems to have fallen through hatches to the lower gundeck (Figure 8.21). The smoothly rounded shape was presumably intended to minimize chafing against the sails. These blocks appear in seven discernable sizes ranging between 140mm and 540mm in length and were built to carry cordage of four basic sizes between 20mm and 60mm. The shells of these blocks are all made of ash except for one example that is oak.

FIGURE 8.21. A *sub-type 2* single block, Fnr 18628 (Photos courtesy of the Vasa Museum).

Controlling the Masts, Anchors, and Cargo: Specialized Top-rope, Stay, Cat Tackle, Winding Tackle, and Mast Tackle Blocks

Aboard a Dutch-rigged warship of the early 17th century there were numerous rigging systems that did not directly pertain to the sails at all. These systems raised and tensioned masts, hoisted cargo, and raised the ship's anchors. All of these were major, heavy lifting operations requiring significant mechanical advantage from blocks. Hence, most of the blocks discussed in this section are large blocks that were rigged in tackles.

Iron Stropped Hook Blocks: Seven of the single blocks found in association with *Vasa* were iron-stropped hook blocks—three even still retained their hooks. These blocks were employed in a variety of the ship's heavier tackles including the top-ropes, the cat tackles, and the mast tackles. Hook blocks are standard wooden blocks, but instead of being stropped with hemp cordage they are stropped with heavy iron bands that are forged together at one end of the block to form a large hook (Figure 8.22). Even without the iron strop and hook, these blocks are easily recognizable. Fitting the iron band onto the block requires that the strop scores be modified by re-chiseling them into flat-bottomed trenches. Then the red-hot iron strop with its forged hook was driven onto the block shell and allowed to cool, shrinking and tightening down into the modified strop score.

FIGURE 8.22. The squared out strop score of a hook block. This particular block is *Vasa*'s port cat tackle block (Photo courtesy of the Vasa Museum).

The seven hook blocks recovered with *Vasa* are all fairly large, ranging from 308mm to 543mm in length. Two were found on the port side of the upper gundeck, two more were stowed away in the rigging locker on the orlop, and the rest lay in the mud around the ship—two being almost right under the bow and the other on the port side, five meters aft of the mainmast.

The two hook blocks under the ship's prow are easily identifiable as cat blocks. These hung from *Vasa*'s catheads, forming the lower end of cat tackles. The hook blocks were lowered to the waterline and hooked onto the anchor as it was brought to the surface. The cat tackle was then used to raise the anchor the final few meters to the rail to be fished and secured for sea (Figure 8.23). The two cat blocks found under *Vasa*'s bow (Fnrs 20517 and 20526) are identical in their shape, style, and dimensions (Figure 8.24). They are both *sub-type 1* single blocks, precisely 480mm long, they have elliptical shells and chamfered edges, and they are cut with a swallow for an 80mm fall. Intriguingly, however, they are not made from the same wood species. One of them has an oak shell while that of the other is ash. This is the only appreciable difference between the two and suggests that neither oak nor ash was better suited for making cat blocks than the other. Both were recovered complete with their heavy iron hook-strops still fitted around them. One of the blocks (Fnr 20526) was actually concreted to one of *Vasa*'s great bower anchors (Fnr 20525).

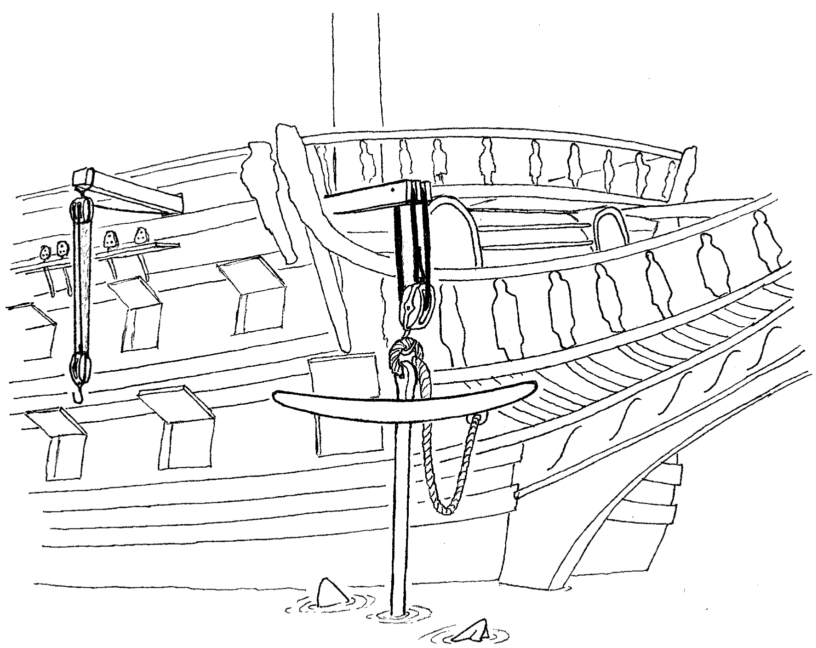


FIGURE 8.23. The cat tackle in use holding the anchor away from the hull and lifting it above the level of the hawsehole. The fish tackle hangs from the fish davit, ready to raise the anchor flukes up to the chainwale (Drawing by Nathaniel Howe, 2011).

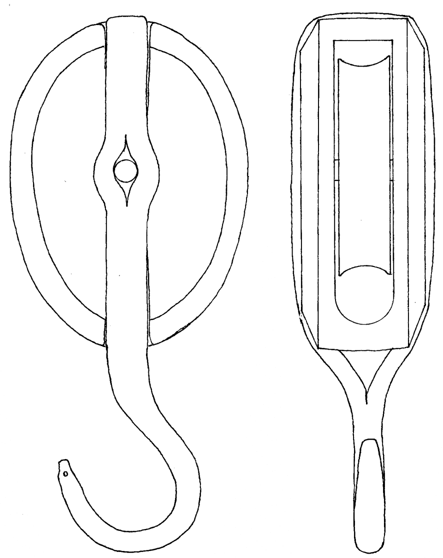


FIGURE 8.24. The form of *Vasa*'s cat tackle blocks, Fnrs 20517 and 20526 (Drawing by Nathaniel Howe, 2011).

The third *sub-type 1* hook block, found in the mud amidships (Fnr 00112), also retained its ironwork (Figure 8.25). The iron strops are crumbling in places, but remarkably well preserved considering that virtually none of the wrought iron in *Vasa* survived.

FIGURE 8.25. The third hook block (Fnr 00112) found with its ironwork still intact (Photo courtesy of the Vasa Museum).

The very presence of the iron strops and hooks on these blocks raises the question of whether or not these hook blocks belonged to *Vasa* at all; they could be more recent depositions, perhaps from one of the subsequent salvage operations. Yet, the striking similarities between the design of these hook blocks and the ship's other, albeit smaller, *sub-type 1* single blocks suggests otherwise. The example concreted to the anchor, in particular, indicates that these blocks are originals from the ship and that the iron simply managed to survive since 1628. Proximity to other large iron objects (the anchors) may have galvanically protected them to some degree. The bottom sediment may have been a factor as well. The find records do not indicate how deep these hook blocks had sunk into the harbor bottom when found, but if they had penetrated down into the clay layer that preserved the iron pintle and gudgeon on *Vasa*'s rudder, there is a reasonable chance that this environment would have also protected the hook blocks.

The two large hook blocks under the bow are clearly cat blocks, but the third example is more difficult to identify. It is identical to the cat blocks, measuring 478mm long with chamfered edges and an 80mm swallow. It is fitted with an iron stropping band 65mm wide and 18mm thick, the two ends of this band meeting at the head of the block where they are forged together into a hook extending 274mm beyond the end of the block. The hook averages 43mm in thickness with an opening of 120mm. There is a small hole in the point of the hook through which a lashing can be rove across the gap to the shank in order to mouse, or tie off, the opening into the hook.

Placing this block in the rig is difficult. Although its form matches that of the cat blocks, its find location—on the ship's port side a little aft of the mainmast—is too far astern to be associated with the anchors. Furthermore, there are already two cat blocks for the two catheads and the gap of the hook in this third block is narrower—too narrow to catch one of the thickly parceled and served anchor rings.

One interpretation of this large hook block is that it was dropped by salvors. This is certainly plausible as contemporary accounts note that "large block hooks" were employed (Cederlund 2006:83). Yet, stylistically this block matches other blocks from *Vasa* to such a degree that it may have been from the ship. One possibility is that it was the lower block of the fish tackle used to swing the anchor up to the fore channels for sea. No other block likely to have served that purpose has been found. Alternatively, the hook block could be from the winding tackle, also sometimes called a garnet tackle or midship tackle depending on the configuration (Anderson 1927:106-108). These tackles were used to lift heavy loads in and out of the main hatch or to hoist the smaller of the two ship's boats (Hoving 2000: 91). The tackle usually consisted of a large hook block on the lower end and a double block or fiddle block on the upper end. The tackle was suspended over the main hatch either by a pair of pendants secured around the maintop and the foretop or by a single pendant from the maintop lashed to the mainstay (Anderson 1927:106-108) (Figure 8.26). It is not clear which configuration *Vasa* carried, but in either case, as long as the pendant to the maintop outlasted the foretop pendant or the mainstay lashing, the block may well have swung aft and to port where it eventually fell and settled into the mud.

The only major problem with this reconstruction is the presence of two very large tackle blocks on the upper gundeck near the main hatch (Figure 8.27). Both have elliptical shells with rounded edges and unusually broad strop scores. One is a *sub-type 2* double block measuring 481mm long. Its strop score is 85mm wide and its swallows have a breadth of 48mm. Beside it lay a huge treble block (Fnr 12884). It is a bulbous 483mm block with the same smooth, rounded edges and similarly broad, 96mm strop scores. Its swallows can carry cordage up to 55mm in diameter over its three large, 363mm ash sheaves. These two blocks were almost certainly rove together and were found in the correct location to be the winding tackle. Stylistically, however, they are somewhat different than any of the other blocks found onboard. Although such differences could simply reflect the fact that these blocks were substantially larger, it may mean that these were not part of the ship's own rig. While they are contemporary with the other *Vasa* blocks—being made with ash sheaves rather than cast iron or *lignum vitae* sheaves that came into widespread use after *Vasa*'s time—these could also be heavy lifting gear lost during the 1628-1629 salvage attempts.

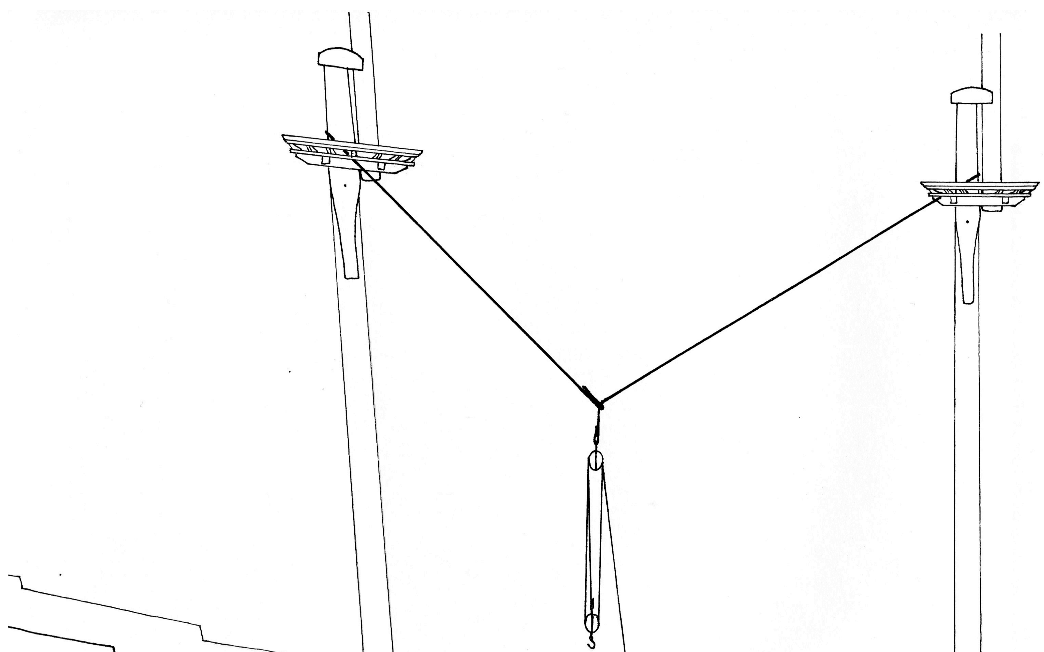


FIGURE 8.26. Dutch winding tackle, supported by pendants from the maintop and foretop (Drawing by Nathaniel Howe, 2011).

FIGURE 8.27. Blocks 12884 (treble block) and 12885 (double block) found on the lower gundeck and possibly from the ship's winding tackle (Photos courtesy of the Vasa Museum).

The pair of hook blocks found stowed away among the spares in the sail locker on the orlop are equally difficult to position in the ship's rigging. They both have elliptical shells made of ash with broad chamfered edges and swallows for 45mm-diameter falls, but they are significantly different in their overall size, one measuring 357mm (Fnr 19906) while the other is only 308mm (Fnr 19904). Given the find location for these two hook blocks in the sail and rigging locker, it is possible that they were used for the main and fore top-ropes, which were always taken down and stowed after the topmasts had been hoisted into position and secured with a wooden fid (Hoving 2000:65) (Figure 8.28). This interpretation is supported by the fact that the smaller of the two clearly saw significant use prior to being stowed. The inside of one cheek has a deep, circular groove worn into it, evidently created by abrasion against an iron sheave found nearby (Fnr 19904) (Figure 8.29). This damage may have been done while raising the topmasts or perhaps while doing other tasks involved in fitting out the ship. If a tackle was needed for a routine lifting operation, the easiest and quickest way to set one up was to fetch a hook block.

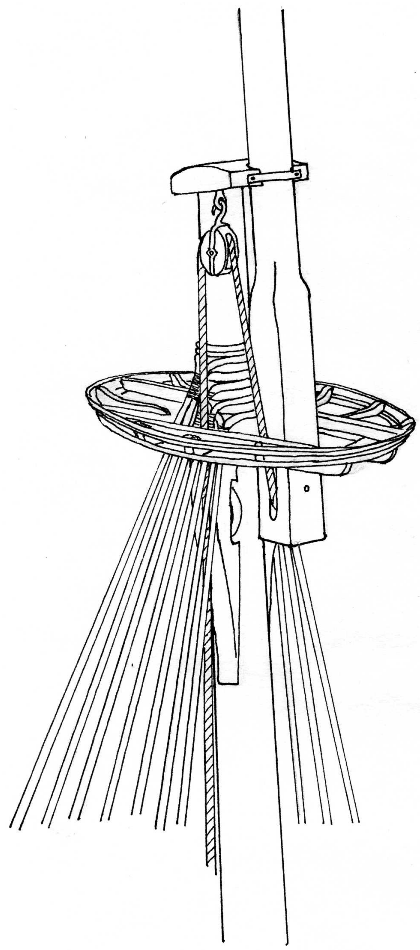


FIGURE 8.28. Top-rope block rigged for raising or lowering the topmast (Drawing by Nathaniel Howe, 2011).

FIGURE 8.29. One of the suspected top-rope blocks, Fnr 19904, (Photo courtesy of Vasamuseet).

The final pair of hook blocks was found on the upper gundeck. These were *sub-type 2* single blocks with lemon-shaped, ash shells and flattened ends. These blocks were considerably larger than those on the orlop, one measuring 460mm in length (Fnr 04078) and the other an enormous 543mm block (Fnr 09149)—the largest of all the hook blocks. The larger of the two lay approximately five meters forward of the mainmast on the port side while the smaller one lay about halfway between the main and mizzen masts, also on the port side. Both blocks have swallows cut for falls of up to 55mm-60mm in diameter and, more intriguingly, both blocks have smooth, rounded edges rather than chamfered edges. This indicates that these blocks were expected to rub against the sails. These may have been the top-rope blocks for the main topmast and mizzen topmast.

The only other position iron-stropped hook blocks were used in the lower rig was in the mast tackles. The find locations for the last two hook blocks, their remarkable size, and the fact that there are only two examples, however, does not support this possibility. It is also possible that these two blocks may have been lost salvage gear rather than a part of the rig at all.

Mast Tackles: The mast tackles are among the lesser known components of ship's rigging, yet these were the most useful and versatile tackles onboard. The mast tackles (also known as side tackles, loading tackles, or midship tackles) were rigged from pendants hung from the main, fore, and mizzen mastheads (Figure 8.30). As many as six of these tackles could be rigged on the mainmast alone. They hung down to the deck level and could be used for a number of tasks. Usually they were employed for moving heavy cargo on deck, but mast tackles could also be used as auxiliary shrouds, running backstays, or to flex the mast and slacken the shrouds so the crew could tighten the deadeye lanyards. Two or three of them used in tandem had more lifting capacity than any other tackle system onboard. At sea, the hook blocks rigged at the lower end of the mast tackles were secured to the channels, just inside the shrouds (Anderson 1927:102 & Hoving 2000:66-69).

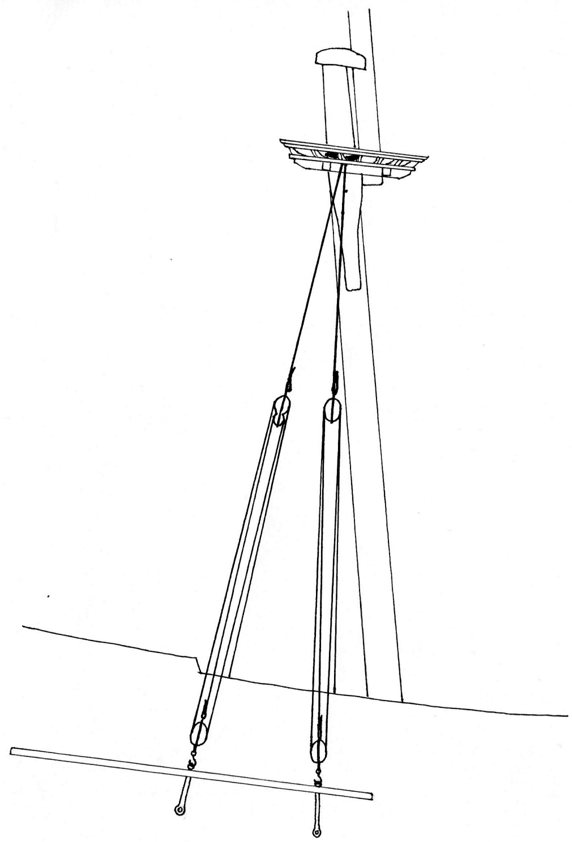


FIGURE 8.30. A common configuration for the mast tackles, just inside the shrouds (Drawing by Nathaniel Howe, 2011).

When setting up the mast tackles, the rigger could choose from a variety of different types and combinations of blocks. Dutch practices alone employed a variety of hardware in different configurations. It is difficult to determine what arrangement was fitted on *Vasa.* Only one potential mast tackle block (Fnr 23466), a lone *sub-type 4* single block, was found near the channels or masts (Figure 8.31). This block lay in the mud below the foremast channels on the port side and it is large enough to have been the lower block of the mast tackle. It is 490mm long with a 50mm swallow. Although large, the block is also compact, being only 125mm thick. Such a flat, thin block rigged to a fiddle block would form a very sleek, low profile tackle easily nested among the shrouds. The block was stropped with cordage that held a hook, or a thimble and hook, at the head.

Five other *sub-type 4* single blocks were recovered from the wreck site that may have also been used in the mast tackles, although their distribution is less supportive. One lay under the bow, another on the lower gundeck just abaft the foremast shrouds, and one was on the orlop. None of these locations were in close proximity to the masts and there are far fewer of these blocks than would be expected if they were from the mast tackles. Yet, no other clear use for such specialized blocks can be determined.

FIGURE 8.31. One of the very thin *sub-type 4* single blocks, possibly used in the mast tackles (Photos courtesy of the Vasa Museum).

The upper end of the mast tackles were usually fitted with fiddle blocks. Yet none were found outside the orlop except for the two that were clearly employed in the spritsail garnet tackles. In fact, *Vasa* was grossly short of fiddle blocks in general. In the 1620s a Dutch-rigged ship of *Vasa*'s size could have up to 25 fiddle blocks in the rig. Eva Marie Stolt's (Stolt 1981) reconstruction of the ship's rig calls for 16 fiddle blocks employed in the lower mast tackles and the spritsail garnet tackles. Fiddle blocks were also often rigged as an adjustable element at the forward end of the fore and main topmast stays, as part of the yard downhaul tackles, as garnet or winding tackles, or in the topsail yard halyards (Hoving 2000:71, 74, 75) (Figure 8.32). Yet only nine were recovered with *Vasa*, four of them being the peculiar non-stropped type, the use of which remains unclear.

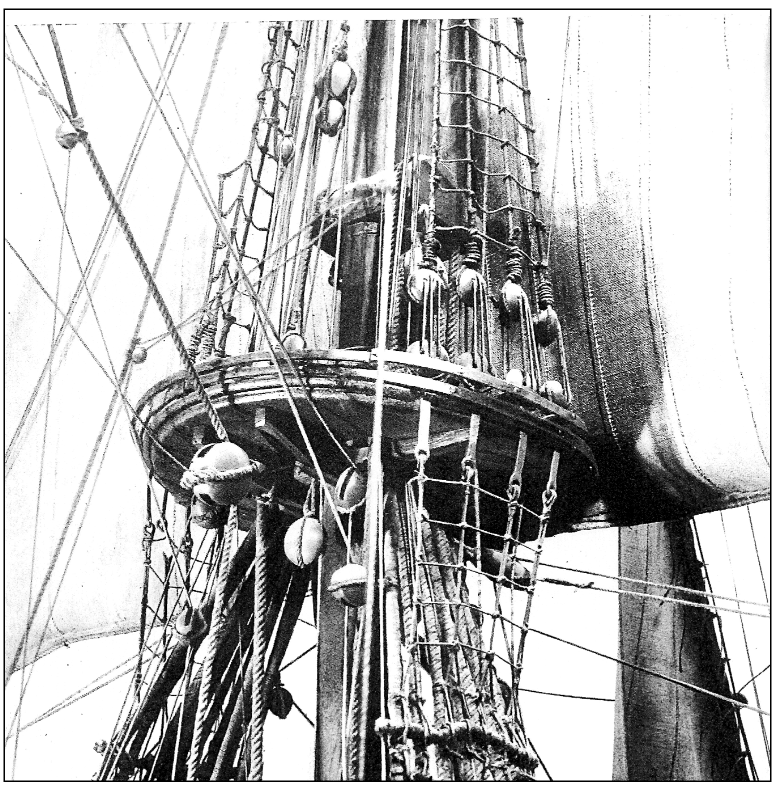


FIGURE 8.32. A fiddle block (top, center) rigged in the foretopsail halyard tackle (Winter 1967:*Tafel* 20).

The more powerful mainmast tackles were often rigged in a runner and tackle configuration comprising three blocks (Figure 8.33). If *Vasa* was fitted with this arrangement, large side-by-side double blocks should also be present. There are none. Given the quantity of mast tackles on a ship as large as *Vasa* and the durability of the pendants from which they hung, the lack of mast tackle blocks in the vicinity of the masts and channels suggests that all of the tackles, and the shrouds surrounding them, were forcibly torn or cut away during the salvage work.

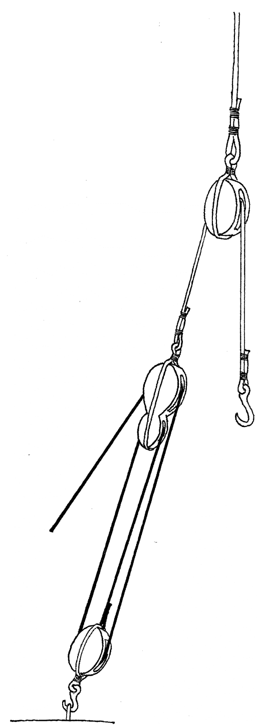


FIGURE 8.33. The runner and tackle configuration for rigging large mast tackles (Drawing by Nathaniel Howe, 2011).

Crane Blocks: Four crane blocks were found in association with *Vasa* (Figure 8.34). These are extremely difficult to relate to a specific function in the rig despite their highly distinctive form. Dutch rigging practice in the early 17th century was highly variable in its use of crane blocks. Functionally, they are just single blocks with a more simplistic mounting. They could be used for everything from anchoring the topsail halyards to rigging temporary hoists. No firm pattern for their use is apparent.

FIGURE 8.34. Pendant block 19905 was found on the orlop and is the only block that definitely sank with *Vasa* on 10 August 1628. Three of the pendant blocks were of this size and form. Only one was double-sheaved (Photos courtesy of the Vasa Museum).

Three of the pendant blocks found on *Vasa* were at the extreme bow, one on the remnants of the weather deck and two lying in the mud below. One of the latter (Fnr 20244) was double-sheaved with two sheaves set side-by-side (Figure 8.35). The fourth was found among the rigging stores on the orlop in compartment T5.

FIGURE 8.35. The double-sheaved crane block (Fnr 20244) found in the mud (Photos courtesy of the Vasa Museum).

Given the crane block's usefulness in salvage operations, differentiating *Vasa*'s own crane blocks from any that may have been lost during the salvage attempts must focus on the block found on the orlop (Fnr 19905). It is the only one that was definitely on board when the ship foundered (Figure 8.34). Its rounded ash shell, 43mm swallow, and solid ash sheave matches the form and styling of all three of the other crane blocks, suggesting they did, in fact, go down with the ship as well. Yet the other crane blocks have no easily apparent function in *Vasa*'s head rig.

It is possible that they were rigged as the pendant blocks in the course martnets as suggested by Anderson (Anderson 1927:170). Another possibility is that they were for the crows-feet of the spritsail topmast backstays, but this would be rather unconventional. Another possibility is that they may have been temporarily fastened to the foremast or stays to facilitate the process of bending on the sails that had just been taken aloft. A third interpretation is that they might be salvage blocks after all. When the ship went down, the Stockholm Naval Yard's chandlery was probably emptied of any equipment that could be used to salvage material from *Vasa*. Identical blocks made by the same men who manufactured *Vasa*'s own rigging hardware would certainly have been among them.

Blocks Not Original to Vasa

A number of the blocks on the upper gundeck and around the wreck site are unlikely to have been on board *Vasa* at all. These scattered examples are inconsistent with the design patterns and styling seen in the majority of the blocks found in association with the ship. Some may be blocks lost during the salvage efforts. In 1629, Admiral Klas Fleming wrote that "both blocks and chains keep breaking when work is in full swing" so he had “the blocks shod with iron” (Hafström 2006:71). Yet, some of the blocks deposited on the site after Vasa sank are clearly not even contemporary to this effort and may have been lost during subsequent salvage attempts in the 1660s or 1680s, diving operations in the 19th and early 20th centuries, or deposited in the harbor by other means.

The most obvious case is one of the two snatch blocks (Fnr 20746) recovered from the *Vasa* wreck site (Figure 8.36). It was found lying in the mud off the starboard bow. Unlike the chunky snatch block with chamfered edges and all wooden construction that was found onboard, this one has a clasped iron strop, a slender shell, and a *lignum vitae* sheave that firmly dates it to a later period. *Lignum vitae* was not used in any of *Vasa*’s blocks and such thin iron very rarely survived the 333 years lying at the wreck site. An almost identical block with the clasp reversed was recovered from the wreck of the HMS *General Carleton* in 1785 (Figure 8.37).

FIGURE 8.36. Snatch block 20746. Not a *Vasa* block as evidenced by its design and the survival of the iron (Drawing and photo by Nathaniel Howe, 2011 and 2007).

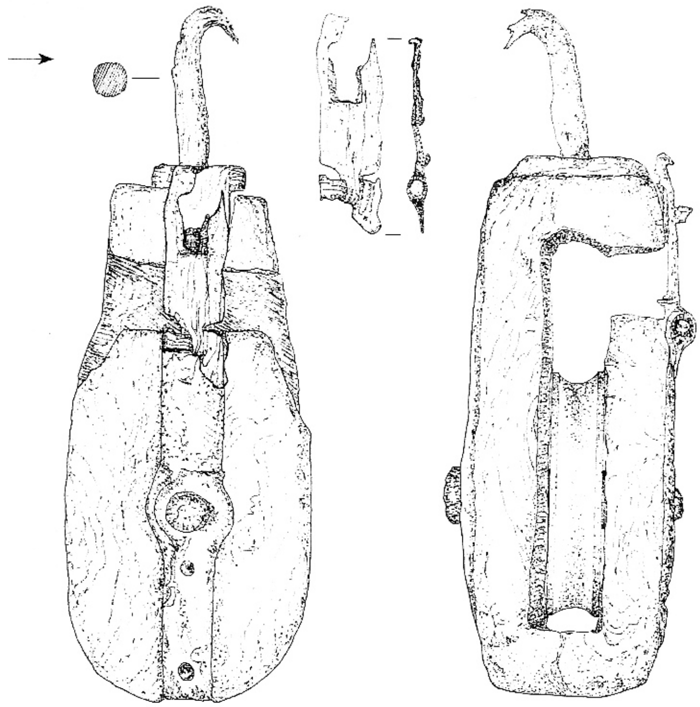


FIGURE 8.37. The hinged snatch block from the wreck of the HMS *General Carleton,* lost in 1785 (Drawing from Ossowski 2008).

The clasped, iron-bound snatch block was broken off abreast of the specialized opening into the swallow, suggesting that it broke during one of the salvage attempts or later diving operations and left its owner with just the head of the block dangling on its pendant. The heavy, iron strop and the negatively buoyant *lignum vitae* sheave took the rest of the block directly to the bottom.

Another suspicious find was a very large treble-sheaved crane block (Fnr 10923) with a passage for a strop or collar at the head found on the lower gundeck. In form, it is a classic ram's head block, possibly for the main topsail halyard (Anderson 1927:183). Yet, minor differences in stylistic detailing and evidence of heavy usage suggest the block is probably not original to *Vasa.* The chamfering of the shell matches the other

Vasa blocks, but the sheave slot has been carved square at both the breech and the swallow. Inside, the sheave mortises have been deeply scored by chafing from the iron sheaves, indicating repetitive use and the iron sheaves are cast in a significantly different style (Figure 8.38). Like *Vasa*'s foremast, it may have been taken from a smaller ship—one that did not require a sheave for the tyes. The fourth sheave placed in *Vasa*'s ram's head blocks to balance the load when bracing the yard to port or starboard was not common (Hoving 2000:72-73). The most likely interpretation for the suspicious ram's head block, however, is that it was a salvage block. Its find location amidships on the lower gundeck is inconsistent with usage in *Vasa*'s rig. In fact, an illustration from a 1691 Swedish shipbuilding treatise actually depicts an inverted ram's head block being used for salvage work (Rålamb 1691:*Tafel* 1). If the tackle fall broke, the big block with its heavy iron sheaves would have quickly unrove and tumbled into the wreck.

FIGURE 8.38. The large triple-sheaved crane block found on the lower gundeck. The shell split after conservation, revealing the deep, circular wear marks left by the iron sheaves (Photo courtesy of the Vasa Museum).

Another suspicious block was found in the mud near the bow. This block (Fnr 20624) has crisp, unchamfered edges and equal length strop scores on both ends. It is the only one of its kind found with *Vasa*, and while it may have been an imported block that had been deposited in the Stockholm Naval Yard's rigging store when *Vasa* was being rigged, it was just as likely dropped from another vessel or lost during a salvage operation. The block has a strikingly different form than *Vasa*'s other blocks, yet it is not an uncommon design. It is nearly identical to dozens of single blocks found on Dutch, French, and Portuguese vessels such as *Amsterdam* (Marsden 1974:121-122), *La Belle* (Corder 2007:23), and *Santo Antonio de Tanna* (Thompson 1988:104).

The most obvious case of an intrusive block find, however, is a late 19th century or early 20th century block (provisionally numbered NN08). It is constructed with a laminated shell and still held together by its corroded, but extant, iron fasteners. Strangely, there does not appear to be any way to mount this block as it has neither a strop score nor a swivel hook or other hardware attachment.

The *lignum vitae* sheaves and sheave fragments found on the site were also intrusive finds. They may have been lost during salvage work, but how they arrived on the site is impossible to say. Other than the sheave in the hinged snatch block, none of them were still fitted in a block shell. If these were from salvage operations, they could have fallen from blocks that were overloaded and shattered, dumping the sheave into the harbor. As *lignum vitae* is denser than water and does not float, these sheaves would have then sunk to the bottom. Although plausible, there is no evidence that these blocks arrived on *Vasa* from such operations. All that can be said with certainty is that they are not original to *Vasa*.

Blocks Missing From the Vasa Collection

The *Vasa* block collection is surprisingly complete for a ship that suffered so much damage and disruption during its three centuries on the harbor bottom. More than 65% of the ship's total complement of rigging, gun tackle, and spare blocks survived, including 30% of the blocks that were actually rigged aloft at the time *Vasa* sank. This collection includes 11 major block types and sub-types representing almost every block design known to have been used aboard Dutch-rigged warships of the early 17th century. Yet a number of key blocks are missing from the *Vasa* collection.

Perhaps the most distinctive loss was the ship's other three Dutch-style combined topsail-sheet and lift blocks. For the purposes of researching and reconstructing the rig, it is very fortunate that at least one of these did survive, but having one from the main-course yard as well would offer much to the reconstruction research, especially in terms of estimating cordage dimensions.

Not a single shoe block was found for the martnets. Yet, this is perhaps to be expected. Although approximately 10 meters underwater after the sinking, these blocks were rigged to the topmasts and could have been recovered with the upper rig. If not, it is also possible that the light-weight cordage gave way after a few years and the blocks, nearly 20 meters above the bottom, drifted a considerable distance with the current before settling into the mud. A third possibility is that *Vasa* was not rigged with shoe blocks for the martnets at all, but used single blocks instead. These would be virtually indistinguishable from the majority of the single blocks scattered on the upper gundeck and around the hull. Regardless, no identifiable part of the martnet system has been found.

Among the many blocks found on the orlop with the small boat sails, none could be directly attributed to *Vasa*'s small boats. These craft, probably sprit rigged, only required half a dozen single blocks and perhaps a pair of fiddle blocks for the running backstay. The lee boards and a windlass for the larger of these boats, *espingen*, were found on the lower gundeck, a possible set of spars for the boat were on the orlop and the sails were in compartment T3. Yet, none of the blocks found onboard can be tied to this ship's boat.

Several smaller variants of the ram's head block should have been found for the fore and main topsail yard halyards and at least another pair for the mizzen course and topsail yards. These would have all carried one or two iron sheaves on a single axle—having no sheave for the tyes as these yards all hung on single tyes instead of doubled tyes (Figure i.1). No such blocks were recovered anywhere on the wreck site even though the corresponding halyard bitts remain as testament to their past existence. These blocks may have all been recovered with the upper rig during the 1628 salvage efforts.

Perhaps the largest gap in the *Vasa* collection is the lack of blocks for the gunport lid tackles. Warships—particularly after *Vasa*'s time period—typically had a simple three-part tackle set up between a pair of single blocks rigged along a deck beam over each gunport. These were used to raise the heavy gunport lids. Yet there is no indication that *Vasa* was fitted with these tackles. There are too few single blocks on the gundecks for the gun carriages, let alone the gunport lids. There is also no evidence of a cleat or ringbolt being mounted on the overhead deck beams. Instead, the cleats over the gunports are positioned to take the gunport lid ropes directly from where they run out of the hull. It thus appears that *Vasa*'s gun crews simply had to open the ports by brute force.

The rest of the missing blocks were duplicates of types that were recovered, but were too few in number. Far too few fiddle blocks were found for the mast tackles, single and double blocks for the gun tackles are in short supply, and a few more dead blocks are needed to complete the bowlines. Given all of the potential applications for blocks aboard a large warship, *Vasa*'s blocks could be underrepresented by several hundred—particularly compared to the quantity that could be expected of a ship of *Vasa*'s size and rig based on contemporary models and artistic representations.

Chapter 9. Block Technology in the Time of *Vasa*

The blocks recovered with *Vasa* provide an unparalleled research collection for examining early 17th-century Swedish (and Dutch) rigging technology. Compared with rigging hardware recovered from other contemporary shipwrecks, Sweden's block designs and production methods appear to have been essentially on par with the rest of Europe. Only the English were stepping ahead of the curve to improve block technology with new and more durable materials.

Judging where *Vasa*'s block technology stood relative to other European maritime powers is unavoidably speculative. Relatively little comparative evidence is available. Few words were written on the subject of block design at the time and the archaeological record is far from representative. The principal sources of comparative material come from a variety of ships spanning more than a century and every vessel type from ocean-going naval flagships to inland ferries of the Zuiderzee. Comparing the elegant bronze sheaves on England's *Mary Rose* to the simple wooden blocks found on a small Dutch merchantman a century later probably reveals much more about the relative investment put into different vessel types than it does about any nation's technological superiority over another. In fact, even to assume that *Vasa* is representative of Swedish blockmaking is inherently tenuous.

Still, a few conclusions can be drawn regarding the design and production of blocks in Sweden—or at least in the Stockholm naval yard. Based on the *Vasa* material, several principle characteristics of Swedish rigging practice and block design are discernable. First and foremost, *Vasa*'s blocks are entirely made of wood except in a few cases where particularly high loads were anticipated. In these cases, cast iron sheaves, or wrought iron strops and axles were employed for extra strength. All of the wood species used for block making were locally available in Sweden and were cut according to a few simple rules. Sheaves were always made of ash, but block shells could be either ash or oak. The ash block shells and the sheaves were slab-cut very close to the center of the tree or limb. Oak block shells were quarter-sawn a few centimeters farther out from the pith. Axles were cut from a thin, but dense, branch or sapling trunk with the pith running directly up the center. Some standardization of key dimensions was employed to ensure reliability and interchangeability. The size of the block shells was regulated through the use of patterns and, based upon examination of blocks made for the same function such as gun tackle blocks, the evidence shows that the blockmakers followed the prescribed dimensions to within 10-30mm. When cutting the swallows or the sheaves, however, the blockmakers used calipers and adhered to much stricter standards. Among blocks intended for the same purpose, the sheaves and swallows were consistent to within 3-5mm. These dimensional standards were maintained by using calipers when cutting the sheaves on the lathe (Moxon 1703:167, 204).

These traits of Swedish blockmaking and rigging practices, as defined by *Vasa*, are largely the same as those pertaining to ships sailing under other European flags. Dutch methods, in particular, appear to have been almost identical. Dutch blocks recovered from the East Flevoland B71 vessel of ca. 1622 (Fred Hocker 2011, pers. comm.), the OH 107 vessel (Neyland and Schröder 1996:60), and others feature very similar all-wooden blocks with essentially identical forms. *Vasa* has long been believed to have been Dutch-rigged and therefore it stands to reason that it would also have been fitted with Dutch-style blocks. Of course, before this can be asserted, it is important to examine the issue of whether or not there even was such a thing as a distinctly Dutch rig. Authors including R.C. Anderson (1927) and Karl Heinz Marquardt (1986), have written and published extensively on 16th, 17th, and 18th century rigging practices. These authors, as well as numerous others, classify rigging configurations into regional variations. Although their arguments are strong, the evidence for these regional rigging methods is limited to contemporary ship models and the work of knowledgeable artists such as Willem Van De Velde (both the Elder and the Younger). The validity of using these to conclude that variations in rigging configuration actually do follow national or regional boundaries is slightly tenuous. It was not backed by any substantial archaeological evidence until *Vasa* and *Mary Rose* were raised. Both had suffered thorough devastation to their rigs, yet both ships are still key to confirming or denying the notion of national rigging methods. *Vasa*, being the only relatively intact ship to allegedly have a 17th century Dutch rig, is in a unique position to grant or reduce the legitimacy of the concept. In some respects, the notion of distinct regional shipbuilding and rigging configurations seems unlikely. Human history and technological development—particularly in post-Medieval Europe—rarely divide cultural practices quite so cleanly along political boundaries. This is especially true of maritime activities wherein the cultures involved are constantly in contact with each other. Yet, contemporary art as well as shipbuilding and rigging treatises strongly suggest that such was the case. *Vasa*, it turns out, also supports the concept of a distinctly Dutch method of rigging. The placement of the bitts, the belaying points, and proportions of the spars are all consistent with the presently conceived tenants of Dutch rigging practice. Moreover, the comprehensive assortment of blocks recovered from *Vasa* also match the types understood to be hallmarks of Dutch rigging. The combined-topsail-sheet-and-lift blocks and the upper lift blocks, in particular, are *Vasa*'s most prominently Dutch types. Although some French vessels carried these same types in the lifts, there is no record of both appearing on the same vessel and these types are much more strongly associated with Dutch vessels (Corder 2007:189-190; Anderson 1927:147).

There are, however, some notable differences between *Vasa*'s blocks and those seen in Dutch paintings and on ship models. The blocks seen in these sources, for example, tend to differ slightly in form, usually having shells carved with bulbous, bearded faces and crisp edges rather than flat faces and chamfering. The strop scores follow a different pattern, extending equal distances from both the head and the foot instead of having a longer score from the head like *Vasa*'s blocks; and they are often made of elm (Hoving 2000: 72, Marsden 1974:121-122, Corder 2007:23, & Thompson 1988:104). The blocks recovered from the wreck of *Batavia* (lost 1629), however, match *Vasa*'s block forms very closely. *Batavia*'s surviving double block and two single blocks (Figure 9.1) have smooth rounded edges and are carved with longer strop scores at the head in the same manner as *Vasa*'s (Green 1989:103-104).

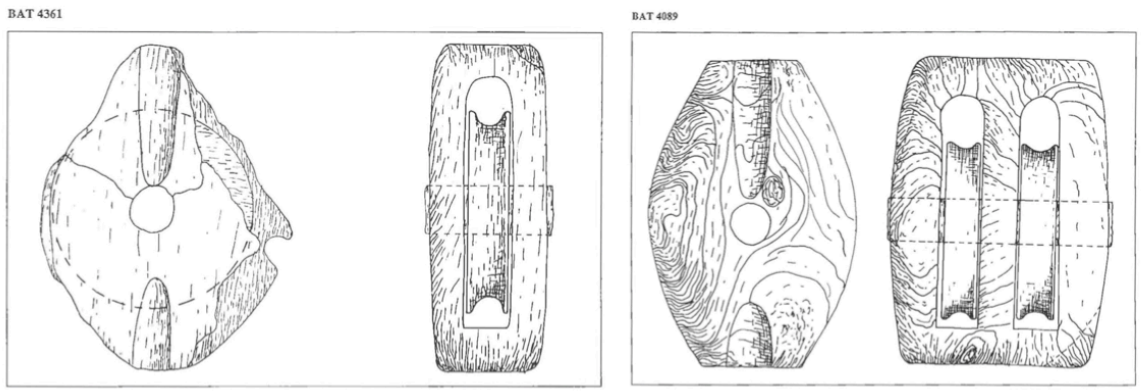


FIGURE 9.1. Blocks recovered from the Dutch ship *Batavia*, lost 1629 (Drawings from Green 1989:103-104).

Blocks recovered from the wreck of *La Belle* indicate that 17th-century French blocks could also have essentially the same form as blocks recovered with *Vasa*--including even some of the specialized types. Aside from having symmetrical strop scores, slightly more bulbous shells, and rounded edges instead of chamfering, the common single and double blocks were scarcely different (Figure 9.2). The fiddle blocks were even more similar, being nearly identical. Yet, fiddle blocks were common to virtually all of the major European sea powers—and appear to have been the favorite type of tackle block for the French (e.g. Anderson 1927:147, 213). The most unexpected find was that *La Belle* also carried Dutch-style upper lift blocks and *Vasa*-like pendant blocks (Corder 2007:23-34). All of these finds feature all-wooden construction with slab-cut sheaves and are more or less identical to *Vasa*'s. The principal difference is in styling. *La Belle*'s blocks are not chamfered. Instead, they are all smoothly bearded with crisp edges (Corder 2007:23-34). Another difference is *La Belle*'s lift blocks are double-ended with swallows at both ends, not just one end like *Vasa*'s (Corder 2007:27). The other specialty blocks, including the fiddle blocks and crane blocks are virtually the same aside from being made of a different species of hardwood and having a slightly more pronounced diamond-shaped cross-section (Corder 2007:26-30).

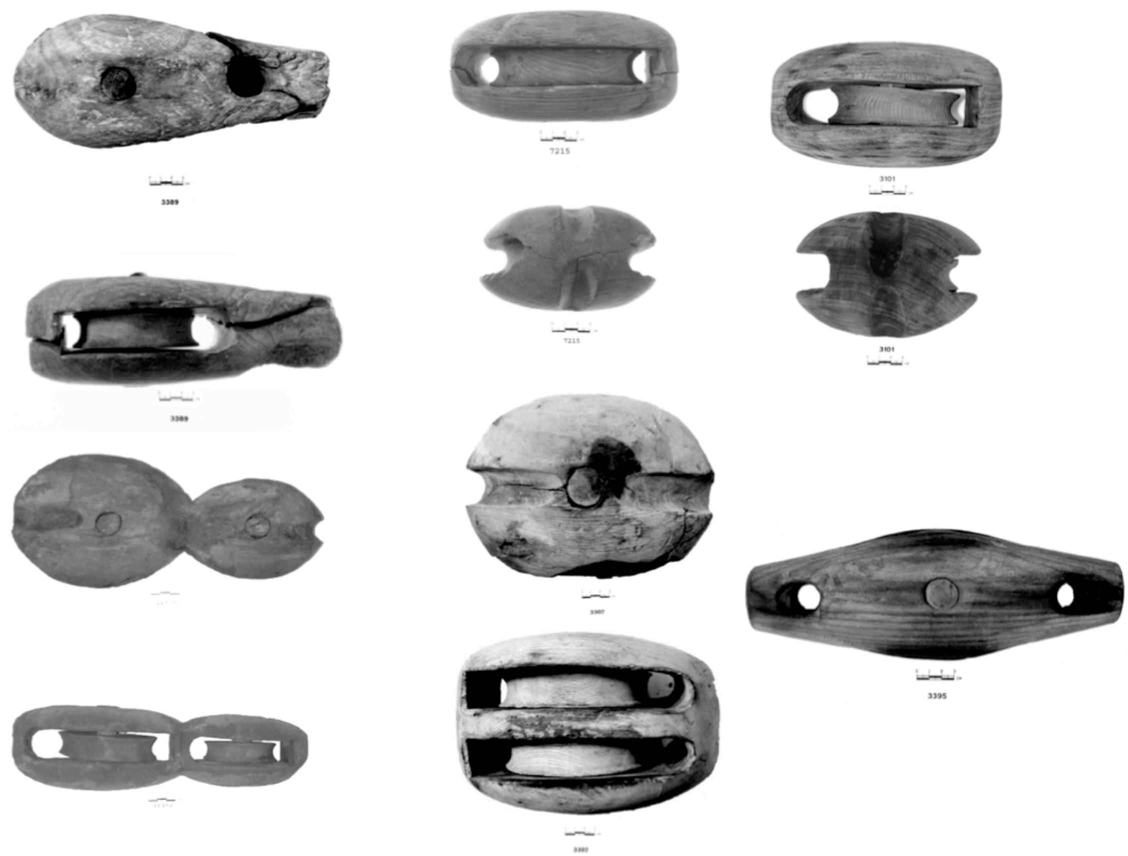


FIGURE 9.2. Examples of the major block types recovered with *La Belle* of 1686 (Images courtesy of the Texas Historical Commission).

Iberian ships were also fitted out with relatively similar blocks. A total of 31 blocks were recovered from the wreck of the Portuguese frigate *Santo Antonio de Tanna*, lost in the Kenyan port of Mombasa in 1697. These include single blocks, side-by-side double blocks, fiddle blocks, a shoe block, and a large crane block (Thompson 1988:91) (Figure 9.3). All of these feature all-wooden construction, but none have the chamfering seen in *Vasa*'s blocks. The strop scores are a mix of symmetrical scores (equal length at head and foot) and the asymmetrical scores seen in Sweden. The lone crane block is the most strikingly different example in that the narrowest portion of the shell contains the sheave. This is highly unusual in any blockmaking tradition. Both of the fiddle blocks on the site were severely degraded, but it is possible to see that the sheave mortises are made in the same manner as *Vasa*'s with rounded swallows and squared off at the lower end. (Thompson 1988:100).

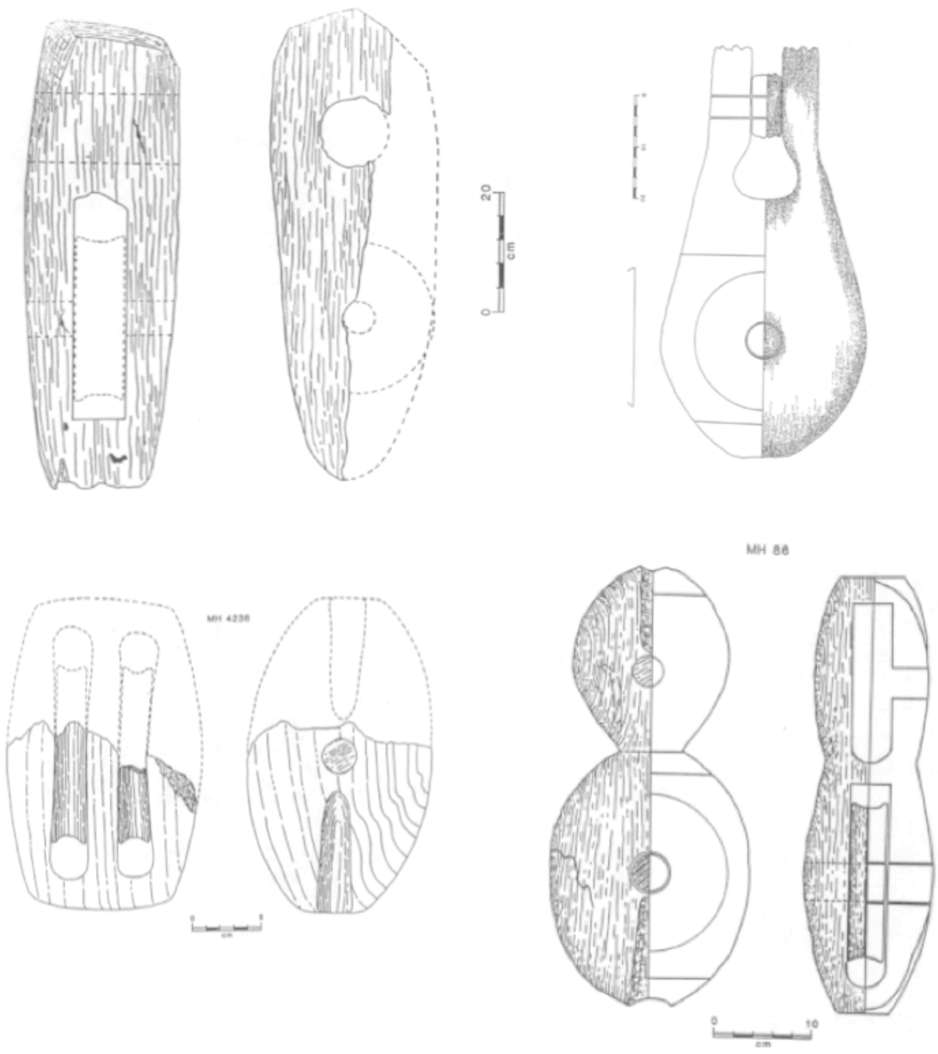


FIGURE 9.3. Blocks from the wreck of the Portuguese frigate *Santo Antonio de Tanna*, lost in Mombasa harbor in 1697 (Drawings from Thompson 1988). A full monogram on the wreck is forthcoming (Bruce Thompson, pers. comm., 2011).

The wreck of the Basque whaler, 24M, at Red Bay, Canada, however, is the most interesting Iberian comparison. This ship, thought to be the whaling ship *San Juan*, provides the only other examples of the non-stropped long tackle blocks found on *Vasa*. Most of these blocks actually have a hole bored through both ends (Grenier et al 2007:IV-14) (Figure 9.4). The upper hole was for a pendant to support the block. The lower pendant hole was probably for the standing end of the fall, serving as a becket. This indicates that they were probably rigged in four-part tackles with another double block, not as three-part tackles with a single block. Rigging these non-stropped blocks insSuch a powerful tackle certainly pushed the structural limits of the block shell.

The rest of the blocks from Red Bay are markedly different from *Vasa*'s. In addition to the six non-stropped long tackle blocks, a common double block and 16 single blocks were recovered (Grenier et al 2007:IV-11). The most notable difference between these blocks and *Vasa*'s is that the Red Bay examples have strop tunnels actually passing through the head of the block instead of just nesting in scores set into the faces of the shell (See Figure 3.13). The shells are all wood, but are either square with a roughly diamond-shaped cross section, or they are bullet-shaped with a square cross-section. The largest of these is only 256mm (Grenier et al 2007:IV-11, 12). The Red Bay blocks are thus both smaller and significantly different stylistically. Only the non-stropped long tackle blocks match those seen aboard *Vasa*.

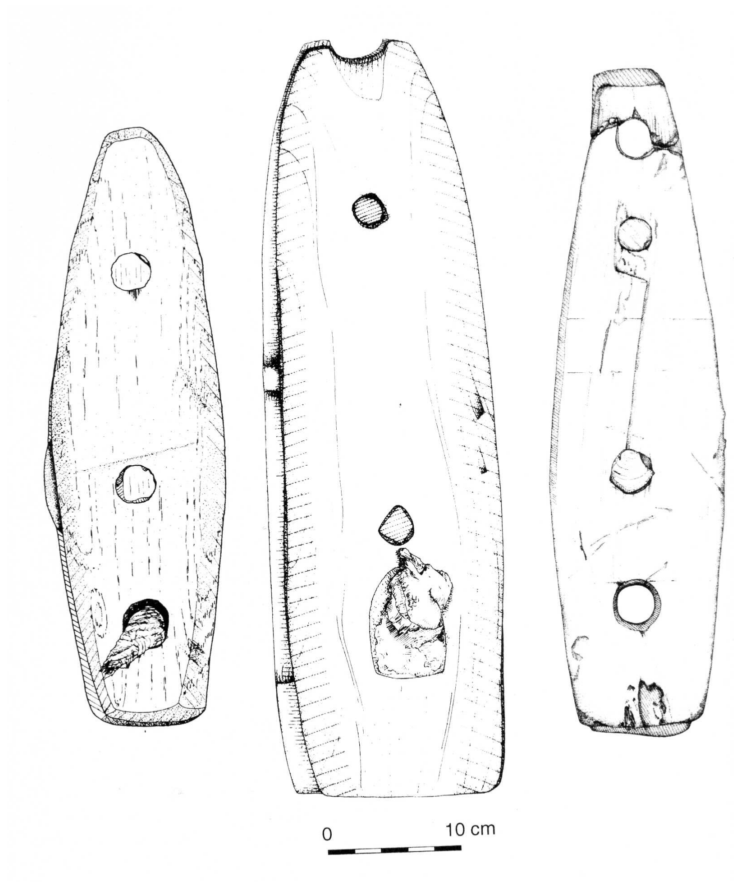


FIGURE 9.4. Red Bay 24M non-stropped long tackle block (Drawings from Grenier et al 2007:Figure 17.1.25c).

Bullet-shaped blocks virtually identical to those found on the 24M Red Bay site with strop tunnels through the crown are also seen on the *Nao de Mataró* model. The model was built about 1450 and was probably a votive model for much of its existence. It is now housed in the Prins Hendrick Maritiem Museum in Rotterdam. The model is still rigged, carrying 35 blocks of two types. The first type is the aforementioned bullet-shaped single block with the square cross-section, pointed foot, squared-off head, and strop tunnels bored through the upper end. The second is a single block with squared off ends and a hole in each end, one for a pendant and the other to serve as a becket. These resemble Dutch lift blocks to some degree, but are rigged in the mast tackles and in the shrouds (Pastor 1992:27-29). Although the *Mataró* pendant block has no direct corollary in the archaeological record, the finds in Red Bay certainly confirm the accuracy of the *Mataró* model's representation of the bullet-shaped rigging blocks as a type commonly used aboard Iberian ships of the 15th and 16th centuries.

English blocks are perhaps the most drastically different from the *Vasa* blocks. This may be because a comparison must be taken from *Mary Rose*, fitted out more than 75 years before *Vasa*. Yet, if the blocks from the *Mary Rose* may be considered representative of English blockmaking, the most pronounced difference between English and Swedish design practices is that English strop scores, as in Iberian blocks, tunnel through the upper end of the cheeks and emerge from the head of the block. The majority of the blocks recovered with the *Mary Rose* are made in this manner. A number of the *Mary Rose* blocks are also made with more ornate block shells that have specialized protrusions and caps (See Figure 3.14). A peculiar acorn-shaped block (80A0958), almost identical to a sister block or an English clew garnet block of the 17th and 18th centuries, are the most impressive of these (Rule 1982:140; Marsden 2009:264). There are a few blocks found on *Mary Rose* that do resemble those aboard *Vasa* 83 years later. A large snatch block (81A0952) is virtually identical to *Vasa*'s apart from a pendant hole positioned perpendicular to the axle (Marsden 2009: 267) (Figure 9.5). *Mary Rose* also had a pendant block or crane block (79A0515) that is almost identical to *Vasa*'s except for the fact that the strop passes through channels at the head of the block. Beyond this handful of published examples the similarities effectively cease.

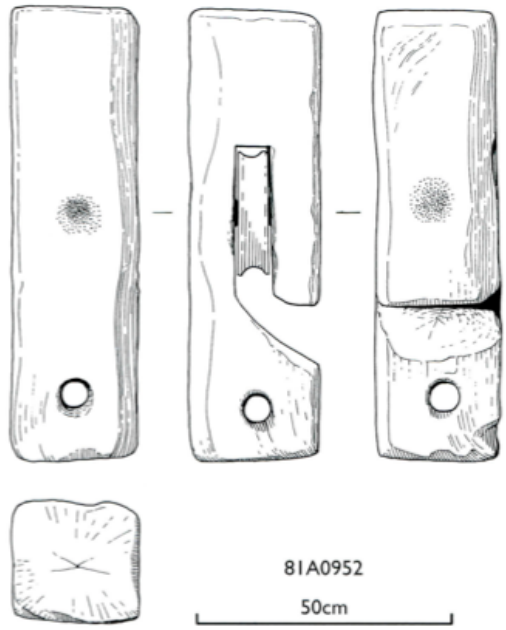


FIGURE 9.5. The snatch block recovered with *Mary Rose* (Drawing courtesy of the Mary Rose Trust).

The biggest difference between English and Swedish blockmaking, as defined by *Mary Rose* and *Vasa* (and thus perhaps largely a difference between the 16th and 17th centuries), is that the English used much more metal for sheaves and axles. Many of the blocks from *Mary Rose* contain bronze sheaves while *Vasa* had only a handful of iron sheaves fitted in blocks (Marsden 2009:267-269). Similar cast bronze sheaves were also found on the wreck of the *Trial*, lost off the coast of Australia in 1622 (Green 1977:43). Although Swedish metallurgy was certainly capable of producing comparable rigging hardware, block production continued to be a predominantly wooden craft. It is unclear why Sweden was slower to adopt metal bearings, axles, and sheaves. It was probably no more than the result of the simple fact that wooden blocks were sufficient for the task and suitable sources of wood were readily available. It is possible that English rigging configurations placed heavier loads on blocks and therefore required stronger materials, or perhaps it was simply a result of the fact that the material culture of Sweden remained heavily wood-based much longer than many other European nations (Hocker 2011:3).

Metal parts were not the only marked improvements in block technology during the 17th century. As the French, Dutch, Portuguese, and other sea-borne empires expanded into the New World, the use of *lignum vitae* (or guiacum wood) as a material for making sheaves became very popular. *Lignum vitae* is strong, hard, rot-resistant, and self-lubricating. By the end of the century, most naval vessels and many merchantmen were rigged with blocks containing *lignum vitae* sheaves (Figure 9.6). Sweden did not gain access to significant quantities of the prized wood until years later. Although the *Vasa* collection seems to indicate that Swedish blockmaking and rigging practices in the 1620s were slow to employ iron and bronze construction in any but the largest blocks, the range of specialized block types, standardized key dimensions, and craftsmanship demonstrate that the trade was still fairly sophisticated in Sweden.

FIGURE 9.6. Block sheaves with bronze bushings from the wreck of the HMS *St. George* (1785), wrecked on the Jutland peninsula in 1811. These sheaves are made of *lignum vitae* and marked with the Royal Navy's Broad Arrow (Photo by Nathaniel Howe, 2007).

In the context of broader European rigging hardware practices, it appears that *Vasa*'s wooden blocks were largely identical to those fitted on ships sailing in most major European navies. All were certainly familiar with the advantages of bronze bearings, iron sheaves, and perhaps even South American hardwoods. Iron parts had been used in blocks for almost 1,700 years and could be found in at least a dozen blocks aboard every 17th century warship. Experience with these blocks showed that they were stronger, more efficient, and lasted longer than wooden blocks. Despite the advantages of blocks with metal parts, the use of all-wooden blocks throughout ships' rigs in *Vasa*'s era was continued. Although technically inferior, wooden blocks certainly did not put any fleet at a disadvantage. The load capacities of wooden blocks were sufficient for most tasks and iron-sheaved blocks could be substituted if necessary (as seen in *Vasa*'s ram's head blocks and cat blocks).

In total, *Vasa* was probably outfitted with over 600 rigging and gun tackle blocks. Even so, comparing the *Vasa* block finds with known patterns of Dutch rigging shows that Swedish rigging and outfitting practices seem to have been minimalist, even if highly specialized. *Vasa* seems to have carried the bare minimum of blocks necessary to operate the rig. This is true even after taking into account the blocks that have been lost or destroyed, but absolutely had to be on board in order for the rig to function. All totaled, the combination of the proportionally low number of tackle blocks for the rig and evidence showing that some tackles (e.g. gunport lid tackles) were never fitted on *Vasa* strongly suggest that the provision of tackles was minimalist by early 17th century Dutch rigging standards. It appears that, if the brute force of half a dozen men would suffice, extra blocks or tackles were not rigged, hence the single-sheaved cat blocks (although the capstan could make up for the lack of a more powerful tackle). Comparable ships elsewhere in Europe carried double-sheaved cat blocks to ease the load. *Vasa*'s minimalist outfitting of blocks was probably inspired by both the abundance of idle hands on board as well as the Dutch emphasis on economical rigging practices such as the dual function topsail lifts that also served as top-gallant sheets. Yet, like Dutch ships, *Vasa* carried more specialty blocks than French, English, or Iberian ships. The functions performed by the combined-topsail-sheet-and-lift blocks, specialized upper lift blocks, and snatch blocks in *Vasa*'s rig were usually fulfilled by ordinary single blocks on foreign ships—except French vessels, which tended to use fiddle blocks as all-purpose specialty blocks.

Chapter 10. Manufacturing *Vasa*'s Blocks: The Working Environment, Tools, and Production Process in Master Turner Mårten Jakobsson's Shop

The collection of more than 29,000 artifacts recovered with *Vasa* offers valuable insight into the social, industrial, technological, and economic conditions of early 17th century Sweden (Hocker 2006:12). Even relatively simple items such as *Vasa*'s basic rigging hardware hold a wealth of information. Based on their form, distribution, and extant tool marks, it is possible ascertain the manufacturing techniques, rigging methods, and even the level of skill employed by those who worked with these simple, but vital pieces of rigging hardware. Gaining insight into the lives of the men who produced the blocks for *Vasa,* however, is much more difficult. Written records pertaining to these craftsmen are extremely rare. Yet, through analysis of their tools, the nature of their work, and accounts from other naval yards and blockmakers' shops in Europe, there is sufficient material to reconstruct at least the occupational environment of the 17th century navy yard turner and blockmaker. Although his world was largely confined to the city and the small shop in which he worked, it was heavily influenced by the sweeping changes in Swedish social organization initiated to support King Gustav II Adolf's aggressive foreign policy.

A Society in Transformation

In 1628 when *Vasa*'s sails were set for the first and last time, it was done against the backdrop of a major transformation in European military and state power. King Gustav II Adolf had overhauled Sweden's armies to make them, man-for-man, the most potent armed forces in Europe (Roberts 1953:196; Petersen 1985:117). A professional officer corps, standardized firearms, and light-weight field guns closely coordinated with infantry movements gave Swedish forces a precious advantage in holding control of the battlefield. In the Netherlands, Maurice of Orange was already instituting similar modernizations, directing sweeping changes in military armament, tactics, and organization often referred to as the "Military Revolution" (Glete 1993:7). Soon, the consolidation of power under a centralized government that held a monopoly on the use of force and the exclusive right to employ it became the established norm for the rapidly strengthening nation-states of Europe (Glete 1993:5).

The modernization of war on the frontlines was supported by an equally comprehensive transformation in the power and organization of the nation-state behind the lines. Between 1612 and 1626, the Swedish king's chancellor, Axel Oxenstierna, reorganized and expanded the courts, the treasury, and the chancellery, necessitating the establishment of a major civil service sector to form all the bureaucratic agencies required to carry out the duties of these branches of government (Peterson:129-133).

One of the many institutions expanded under the modern nation-state was the Stockholm navy yard. During the early 17th century when *Vasa* was built, naval dockyards were among the largest organized concentrations of industrial activity in Europe (Goad 1983:15). This remained true until the start of the Industrial Revolution and the construction of major manufacturing plants. The Stockholm navy yard was not a dockyard. It did not really become one until the 1850s when a graving dock was finally constructed (Cederlund 2006:151). Although the term 'dockyard' has come to mean a naval base where ships may be repaired, outfitted, armed, victualed, or even built

(Cederlund 2006:40), navy yard is the more accurate title for the facility that built *Vasa*. The word 'dockyard' is primarily an English term reflective of the fact that English naval yards included graving docks from a very early date, the first was constructed in Portsmouth in 1495 (Goad 1983:19). Other European powers did not build graving docks until the early 18th century and, until that time, these shipyards—like the Stockholm navy yard—relied on beaching or careening in order to work below the waterline on their respective warships (Glete 1993:65).

The Stockholm navy yard, set up just across the channel from the royal palace, was the largest single employer in Sweden during the early 17th century. More than 300 craftsmen are listed on the surviving payroll records, ranging from master shipwright Henrik Hybertsson down to two sauna tenders (Cederlund 2006:40; Cederlund 1966:34-37). Among them is a master turner by the name of Mårten Jakobsson (Cederlund 2006:40). It was his responsibility to outfit *Vasa* and any other naval ships calling at the Stockholm navy yard with rigging and gun tackle blocks and other assorted items requiring the skills of a turner. Reconstructing the occupational environment of this man, about whom virtually nothing is known, must begin with the operational structure of the shipyard.

In the mid-1620s, King Gustav II Adolf and Axel Oxenstierna were still laboring to build up the civil service infrastructure of the Swedish nation-state. There were not enough trained bureaucrats to manage both the army and the navy production concerns (Cederlund 2006:41). To alleviate the shortage, a system called *arrende* was instituted in 1615 to contract the management of certain installations, including the Stockholm navy yard, to private contractors (Cederlund 2006:39-41). The *arrende* system was, in function, a contract under which a private administrator or yard foreman oversaw all operations related to a specified activity on behalf of the king, including the hiring of sub-contractors, labor, and the acquisition of supplies and raw materials (Cederlund 2006:41). The crown would supply funds and a supervisor to watch over the interests of the state (Cederlund 2006:42).

The first *arrende* for carrying out all new vessel construction and maintenance at the Stockholm navy yard was issued to Antonius Monier in 1620. The following year, the *arrende* was renegotiated to include a Dutchman, Henrik Hybertsson, to join Monier. In 1625, Hybertsson and his brother, Arendt, signed a new contract to direct the construction of four new ships, including *Vasa* and its sister ship, *Äpplet*. The Hybertssons then hired master craftsmen to oversee the navy yard's major operations, including shipwrights, blacksmiths, and a master turner. Mårten Jakobsson was hired in the latter position (Cederlund 2006:41).

Employment in the Stockholm Navy Yard

Mårten Jakobsson's name in the payroll records signifies the first major influence on his working environment. Unlike most men in his trade, Jakobsson did not own his own shop. Working in the king's navy yard, he was first and foremost an employee of the Crown, and secondly responsive to the crown's contractor, Henrik Hybertsson. Although Jakobsson was master of the turner's shop, he was subject to orders from above. Hybertsson's authority carried implications for almost every aspect of Jakobsson's work, affecting all facets of production and shop organization from the work schedule and materials procurement to the selection of journeymen and the development of block design standards.

In the 17th century, blockmaking was a sub-specialty of wood turning. Turners, who produced their handiworks on a lathe, usually went on to own their own turner's shops once they achieved master status. They specialized in wood, bone, or metal and produced everything from chair and table legs to ivory chalices (Knutsson and Kylsberg 1989:305). Blockmaking became the domain of the turner principally because the sheave inside the block had to be made perfectly circular in order to run smoothly. In particular, the broad groove cut into the circumference of the sheave for carrying the fall could only be efficiently and evenly cut using a lathe. The carving of the block shell, although not possible to do on a lathe, also became the turner's responsibility (Cooper 1984:189). The concept of vertical integration in production would not be articulated for centuries, but it was, in essence, the way most craftsmen of the period operated. They obtained the raw materials for their craft themselves and then completed the item from start to finish in their own shops (Cooper 1984:194). Each artisan personally transformed each piece from raw material to finished product. The blockmaker not only turned the sheaves, but also carved the block shell, cut a suitable piece for an axle, and assembled the block into a completed product ready for release to the chandlers or to the riggers to take aboard ship.

Although a turner's shop was ultimately part of most naval yards, they did not necessarily have to be attached to a shipyard at all. Most privately operated shipyards and boatyards were too small to warrant their own turner's shops for blockmaking. Also, because blocks are relatively small and interchangeable pieces of independent hardware, they could easily be produced off-site and transported to a yard or chandlery. Most

English naval yards, for instance, purchased a substantial portion of their inventory of rigging and gun tackle blocks from private blockmaking shops up until mechanized blockmaking processes were introduced in 1805 (Cooper 1984:186). This both reduced the administrative and facilities overhead for the shipyard and also allowed the master craftsman to retain complete control over his own shop.

The blockmaker who joined the navy yard had to give up this autonomy. No longer was he the master of his own business, but he became a wage laborer on contract to the state or, in Mårten Jakobsson's case, to the state's private contractor. His productivity was dictated by the needs of the navy and his resources limited by the same authority's interest and ability to supply him (Beach 1672:101). Working as a navy yard turner was not particularly lucrative. Jakobsson was paid less than the carpenters in the yard and, unlike the independent turner working outside the state system, he could not increase his income by working harder and increasing his output (Cederlund 1966:34-37; Hocker, 2011:13). As a wage laborer, boosting productivity offered no real reward. As long as he worked at the navy yard, his prospects for social mobility were limited and his standard of living would remain fixed.

The loss of autonomy and the lack of opportunity to increase earnings was somewhat balanced by the increased employment security provided by the state. For a specialized craftsman such as a turner, the whim of the state was probably less volatile than the whim of the commercial market. Blockmaking in the turner's shop was probably one of the most stable trades in the navy yard. Indeed, all of the craftsmen responsible for working on ships' rigging were likely to find steady employment. Sails, blocks, and cordage underwent constant strain, wear, and abrasion. Consequently, these relatively vulnerable items of limited resilience regularly wore out, creating constant demand (Goad 1983:68). Both new construction as well as the aged ships of the fleet needed to replace rigging equipment fairly often. Although one of the British Royal Navy's block suppliers once guaranteed their products for seven years, large warships rigged with up to 650 blocks could be expected to split, break, or shatter a number of those each season—particularly if they saw action (Cooper 1984:183, 189). This was particularly true during the era of Jakobsson's employment in the Stockholm navy yard, when blocks were still made from solid wooden shells without any metal bearings or South American hardwoods.

The shipwrights, carpenters, and even the caulkers were much more vulnerable to fluctuations in naval activity and construction programs. Caulkers could only work when ships were in port—and usually only when they were careened or dry-docked. Shipwrights and carpenters were even more at risk for being dismissed during lulls in shipyard activity. When a shipbuilding program was underway, they were in great demand; but if a moratorium was placed on new construction, they could find little work. Ships coming in for repair and maintenance invariably required the attention of ships' carpenters and shipwrights, but the need never exceeded a handful of men. After commissioning a finished vessel, a great number of men could be laid off and there was no guarantee that the naval administration had the funds to issue their back pay. A letter from English Master Shipwright Phineas Pett, of the Chatham Naval Dockyard in March 1673 to the Navy Board states,

> An estimate of the wages of several workmen, in order to their discharge out of his Majesty's works here, such as were last prest and have least money due to them. When I gave your Honors the late account of the several numbers of each calling fit to be continued (now in time of peace) for the carrying on of present

> works (excepting the rebuilding of the *Old James*) upon consideration had the purging of the yard of a great many idlers and insufficient persons (Pett 4 March 1673 in Rodger 1984:116).

The blockmaker was not subject to fluctuations caused by surges in construction programs to the same degree as some of the other navy yard craftsmen and laborers. In part, this was also because blockmakers were responsible for a number of other fittings and hardware in addition to rigging blocks. Blockmakers often turned belaying pins, parrels, thimbles, toggles, and pump plungers. These additional products could keep the master turner and his apprentices busy even when demand for blocks was low (Cooper 1984:209). If even that work dried up, a turner like Mårten Jakobsson was still shielded from any reductions of manpower in the yard. The *arrende* allowed the master craftsmen to decide whom to employ in their shops and, if necessary, lay them off to protect his own position (Cederlund 2006:40).

The need to release men from the turner's shop, however, was a rare situation. For the most part, demand in the navy yard was constant and much more predictable and stable than in private yards. Even though the size of the Swedish fleet was constantly changing due to wartime losses and construction programs, craftsmen in the navy yard could still anticipate the rough number of ships expected to call at the yard for maintenance and repairs each year. For the Stockholm navy yard, as well as English yards during the period prior to the year-round deployment of naval fleets in the late 17th century, most of these ships arrived in the mid to late fall for winter demobilization. If they required more blocks than the turner had amassed in the rigging stores, there was little rush to turn out the remaining blocks required for the ships as they would not re-rig for sea again until spring. The entire winter remained available to produce these blocks.

The number of vessels calling at a commercial yard, however, was almost entirely dependent on the cycles of boom and bust in the merchant cargo trade and the efforts of competitors attempting to undercut the shipyard turner's bid.

The increased employment security of a turner working on contract to the state was partly due to the fact that such competition was almost nonexistent. In the commercial sector, turners vied with one another for business. Guilds were created in large part to temper and mediate this competition—and to ward off foreign competition. The turner working in the navy yard, however, enjoyed a long-term exclusive contract with Hybertsson and the state. Competing with independent turners offering to do the work for less every time another ship arrived in port was not an issue. Unless there was suddenly an urgent need for a large number of blocks, the navy would not seek to obtain blocks from turners outside the navy yard. Thus Jakobsson was able to carry on his work without the constant need to curry favor with local merchants and chandlers in order to compete for business.

In addition to having a more stable trade, the blockmaker also had a much safer, more comfortable occupation than many of the other workers in the navy yard. The blockmaker worked in a small, enclosed shop that could be easily heated in the winter. The work he performed required only a steady hand and a good sense of timing, but not much muscle. Pumping a foot on the treadle to power the lathe all day was certainly intensive, but not as arduous or potentially injurious as swinging an axe or driving bolts. The blockmaker had a very safe job where the only dangers were the sharpness of his small gouges, chisels, and scrapers, and the weight of the block shells he had to heft around the shop. Conversely, blacksmiths, shipwrights, and riggers routinely worked in discomfort and danger. Blacksmiths worked over the searing heat of their forges, risking burns and were dogged by the deafening ring of hammers all day long. Shipwrights and carpenters working out in the yard in all manner of weather spent much of their workday sawing and hewing heavy timbers and then hoisting and leveraging them up to the ship, sometimes into precarious overhead positions. Toppling planks and frames could crush feet and skulls alike, while there was the ever-present danger of falling from the scaffolds, particularly in winter when frosts covered the yard. Riggers, working aloft on ships that usually still lacked the footropes, ratlines, and jack lines that the sailor relied on to avoid a fall, daily risked a deadly or debilitating fall (Goldenberg 1976:92). These dangers and discomforts were not part of the blockmaker's experience. An aching back after a long day crouching over the lathe was the worst with which a turner typically needed to concern himself (Moxon 1703:182).

This relative safety from workplace injury may have been more deeply appreciated by the blockmaker employed in a naval yard than by his free enterprise counterpart in town. A blockmaker working from his own shop for the commercial market was typically a member of a turners' guild or ship carpenters' guild. Centralized state control over the activities in the state-owned naval yards, however, may have interfered with this connection to the turner's professional peers. In recent times, guild and union politics have only been begrudgingly tolerated in state facilities. Yet, for more than 1,000 years, guilds were extremely common among the skilled craft trades in Europe (Knutsson and Kylsberg 1989:305). Among the many functions and services provided by the guilds were provisions for supporting disabled or retired members (Unger 1978:93). If membership in the guild was incompatible with employment in the navy yard (there is no indication either way) by mandate of either the guild or the navy, the naval blockmaker would not have had the disability benefit provided by guilds and therefore had much reason to be thankful for the relative physical safety of his trade.

If Jakobsson was a member of a local guild, it was probably a shipbuilders' guild, not a dedicated turner's guild. Many European towns and cities did establish formal turners' guilds. The earliest known example was formed in Köln in 1182 and another appears in records for Lübeck in 1507 (Knutsson and Kylsberg 1989:305). The first Swedish turners' guild, or *svarvareämbetet*, was founded in the southern port city of Kalmar in 1586. Farther north in Stockholm there is no record of a turners' guild until 1647 (Knutsson and Kylsberg 1989:305), nearly 20 years after Mårten Jakobsson fashioned blocks for *Vasa* in the Stockholm navy yard. Although earlier records of the guild may have been lost during the past four centuries, it is more likely that the city simply did not have a turners' guild. The presence of such guilds was dependent upon the number of artisans of a particular trade working in a municipality. As the population of turners increased, they could form their own guild. As the number continued to increase, they could eventually split into sub-specialties such as furniture turners or metal-working turners. By the late 17th century, blockmakers in large cities such as Stockholm, Ystad, and Göteborg were able to form their own guilds resulting in dedicated *blockmakarämbeter* or blockmakers' guilds (Knutsson and Kylsberg 1989:305). In smaller cities, or in the years before the trade grew such specialized guilds did not exist. In these cases, blockmakers typically joined general turner's guilds or, more commonly, the ship carpenters' guilds. This was common in Dutch shipbuilding towns along the banks of the Zaan and was probably also true in Stockholm during the early years of naval expansion before the turners formed their own guild (Unger 1978:93).

The most important function of the guilds during the period was in prescribing the qualifications for journeymen to become fully trained, independent, master craftsmen. According to the Swedish historians Johan Knutsson and Bengt Kylsberg (Knutsson and Kylsberg 1989), a journeyman in the Stockholm *svarvareämbetet,* or turners' guild, took six years to complete his education. Turners seeking to produce artistic pieces in metal or bone generally took an additional two years to be approved by the guild (Knutsson and Kylsberg 1989:305). Mårten Jakobsson is the only master turner listed on the Stockholm navy yard payrolls at the time *Vasa* was built, but payrolls from the 1610s show two journeymen and three apprentices working in the turner's shop (Hocker 2011:13). Based upon such records, it appears that *Vasa* and the other ships calling at the navy yard required the labor of half a dozen turners producing everything from blocks and parrel trucks to belaying pins and bilge pumps. If Jakobsson was part of a turners' or ship carpenters' guild, these institutions probably had a voice in determining whom he took as journeymen and apprentices in his shop.

There is evidence in the archaeological record of these additional people working in the block shop. Several dozen single blocks have strop scores that angle slightly to one side or the other (Figure 10.1). These irregularities occur regardless of the grain direction, indicating that the chisel was not simply led off-center by wavy grain. The usage of the brake (a device for gripping the block while chiseling) does not account for this recurrence either. Instead, the pattern indicates that the chisel was brought to bear at an angle consistent with either a right- or left-handed craftsman. The frequency of this error and the simplicity of chiseling out a strop score can be interpreted as possible evidence that this work was done by young apprentices in Jakobsson's shop. If so, there was at least one right-handed apprentice and one left-handed apprentice. There are clear examples that both were present in the shop (the best examples include Fnrs 09509, 15376, and 05087).

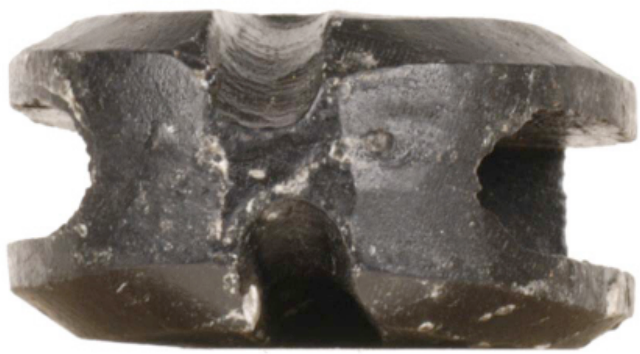


FIGURE 10.1. Block (Fnr 16490) with crooked and misaligned strop scores (Courtesy of the Vasa Museum).

Not only did these apprentices often fail to keep their chisels centered, some made more glaring mistakes. One of the single blocks (Fnr 11551) has a sheave mortise cut with rounded ends at both the head and the foot of the mortise instead of squaring out the breech. Another block (Fnr 04024) is just carelessly cut—or perhaps the mark of someone's first day on the job. Yet another single block (Fnr 10180) has an upper strop score wrapping up over the head of the block as if it were a strop score cut for the foot. Half way over the head the score suddenly stops (Figure 10.2). The mistake had been caught and, likely after some harsh words, was forgotten for the next 380 years. Fortunately for that apprentice, although his mistake has been rediscovered, his name is long forgotten.

FIGURE 10.2. A double block bearing a major mistake by the blockmaker in the strop scores (outlined by the dotted white line). This is the head of the block, yet the score was gouged out to create the wrap-around score typically done for the foot of the block. Half way across the head of the block the score suddenly stops as the mistake was noticed. This mistake surely cost the craftsman some face, but would not affect the performance of the block (Photo courtesy of the Vasa Museum).

The Turner's Shop and the Blockmaking Tools

Mårten Jakobsson's blockmaking shop was probably one of the several workshops arranged around the triple-chimneyed smithy set up beside the building and launching ways (Figure 10.3). At the heart of the navy yard, it was a highly social place. Dozens of blacksmiths, carpenters, ornamental carvers, and other shipyard workers passed through the small open square between the workshops. It was probably a fairly noisy setting, particularly beside the forge where the blacksmiths' hammers rang all day as they pounded out iron bolts and nails for the shipwrights who drove more than 10,000 iron fasteners into *Vasa*'s hull (Cederlund 2006:276).

FIGURE 10.3. Reconstruction model of the Stockholm navy yard production shops where the blockmaker's shop was probably located (Courtesy of the Vasa Museum).

In its design, the blockmaker's shop was not particularly unique. A turner's shop of the 17th century could be set up in almost any room of moderate size. The only design requirement was that it have sufficient interior height for an overhead spring pole (Goad 1983:64). This type of lathe was widely used throughout northern Europe during the period. Wheel-driven lathes were also available. Some of these were powered by a foot treadle, but most were driven by a belt or cord carried to a large wheel that was turned by a shop assistant. As these required a second person to keep the wheel turning, they were less economical and thus less common (Knutsson and Kylsberg 1989:303). It is not known which type Mårten Jakobsson used, but as the principal tool of the master turner, the lathe he operated defined his workspace and was the center of his attention throughout the day.

The finest description of a 17th-century lathe and its use comes from a 350-page treatise written by Englishman Joseph Moxon. The work is titled *Mechanick Exercises: or the Doctrine of Handy-Works: Applied to the Arts of Smithing, Joinery, Carpentry, Turning, and Bricklayery* (Moxon 1703). The section on turning is just shy of 70 pages in length and describes the tools and their usage in detail. The text is heavily technical, but a number of important aspects affecting the occupational environment and skill of the blockmaker can be gleaned from the writing.

Moxon focuses his manuscript on the spring pole lathe, which operates by passing a cord from a foot treadle up to the piece of work to be turned on the lathe, wraps around it a few times, and then continues up to an overhead spring pole (Figure 10.4). The craftsman depresses the foot treadle, drawing the cord downward. Being wound around the work on the lathe, the cord makes it spin. As the other end of the cord is fastened to the overhead pole, drawing down on the string by depressing the treadle flexes the spring pole downward, increasing the tension in the cord. When the craftsman lifts his foot off the treadle, the flexed pole draws the string back upward again, spinning the work on the lathe in the reverse direction and resetting the apparatus (Moxon 1703:167-178). The turner applies his cutting tool to the work as it spins on the down-stroke. Then he pulls his tool away when it reverses direction and the apparatus resets. Each cycle takes only a few seconds, depending on the speed applied by the operator.

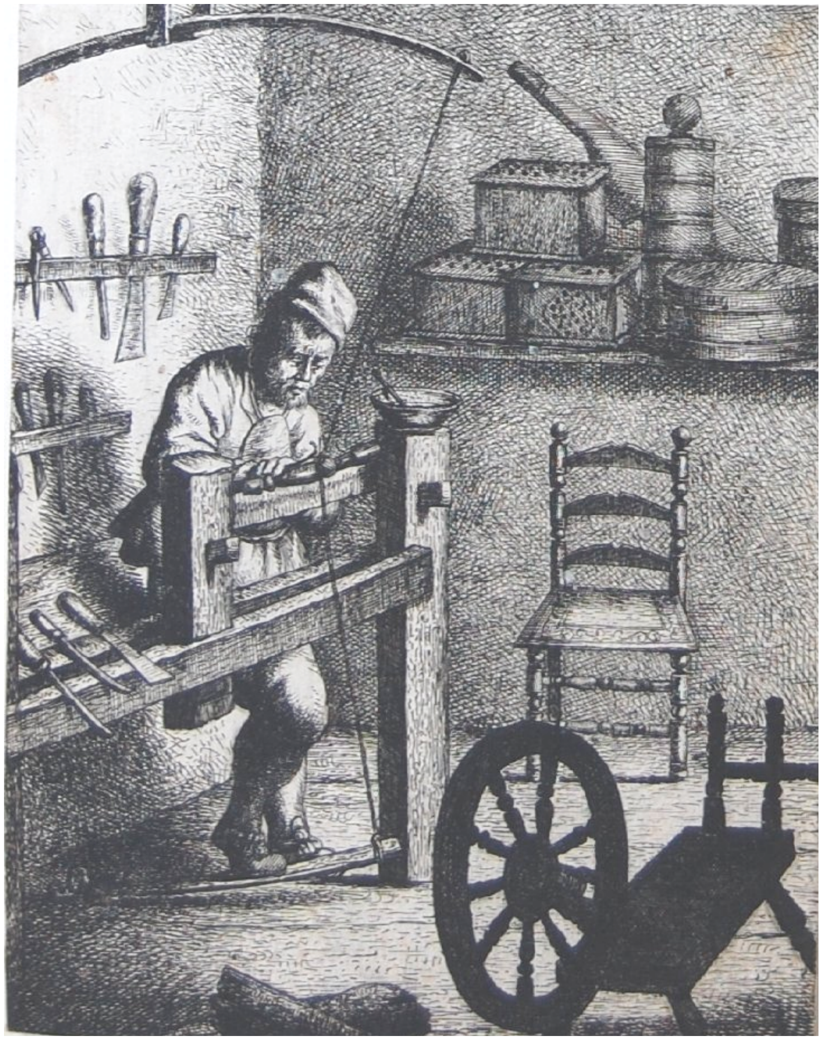


FIGURE 10.4. A copper engraving of a turner working on a spring pole lathe by the Dutch artist Jan Joris Van Vliet (1608-1650) about 1635. Print held at the British Museum, catalog number F,6.2011 (Image courtesy of the Trustees of the British Museum).

The lathe itself (Figure 10.5) consisted of two heavy, wooden legs or stiles connected by two long timbers known as the cheeks, or sides, that bracketed the tops of the stiles. Between the cheeks were two moveable posts called puppets that could slide along the cheeks that, together, formed a track for the puppets. The work was placed between the puppets, which were then adjusted to fit the length of the piece. The axis of rotation lay between the tops of the puppets. One puppet had a pike set into its face. The other puppet had a corresponding screw with a handle on it. The work was centered and clamped between the pike and the screw. Once the puppets were wedged in place, the screw was tightened down to lock the piece on the axis (Moxon 1703:167-168).

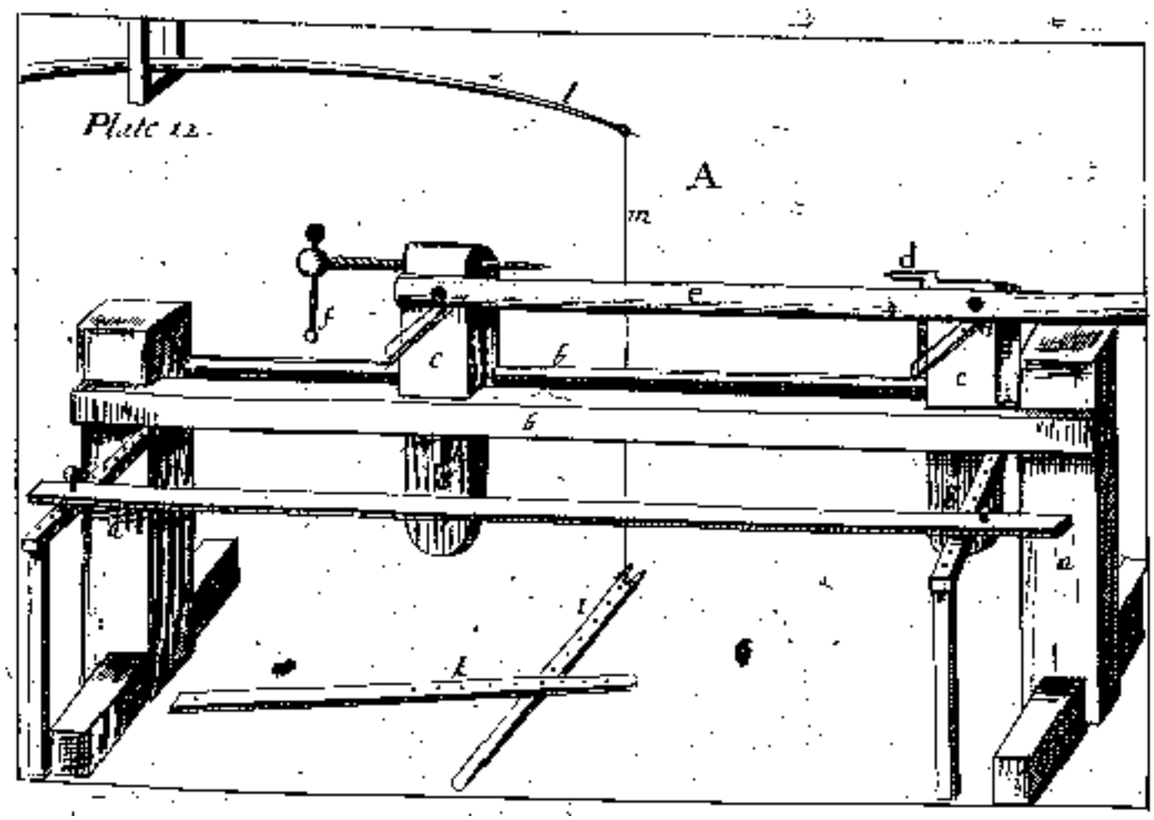


FIGURE 10.5. A diagram of a spring pole lathe. The component parts are (*a*) the stiles, (*b*) cheeks, or sides, (*c*) puppets, (*d*) pike, (*e*) rest, (*f*) screw (Moxon 1703:168).

An adjustable rest was placed between the puppets, a few inches off-center. "Its Office is to rest the Tool upon, that it may lie in a steady position while the Workman uses it" (Moxon 1703:172). This also prevented the tool from catching on the spinning object and causing it to jump, chatter, or gouge the work.

Overhead, the spring "Pole is nailed (or indeed rather pinned) up to some Girder, or other Timber in the Ceiling of the Room, with only a single Nail or a Pin, as on a Center, and its thin end pass from one Puppet to the other, as the Work may require" (Moxon 1703:172). This overhead pole provided spring action to reset the system after the craftsman's foot depressed and then released the treadle. The pole was also the only item of the turner's equipment that placed a requirement on the building. There had to be sufficient clearance over the lathe for this pole to move.

Some lathes made use of a treadle wheel or a "Great Wheel." The latter resembled a spinning wheel, which was mounted on a small bench a short distance from the lathe. A cord was passed around the circumference of the wheel and then to the work fitted on the lathe. The cord wrapped around the work a few times to establish a firm grip on it, and then returned to the loop passing around the great wheel. The wheel was powered by an assistant cranking a handle attached to the hub. The treadle wheel functioned in essentially the same manner, but fit beneath the lathe and was rotated by carefully-timed exertions on a treadle bar. The end of the bar was connected to a point near the outer circumference of the wheel by means of a leather strap (Moxon 1703:178-180). This same mechanical principal for driving foot-powered machinery can be seen on the peddle-driven Singer sewing machines of the late 19th and early 20th centuries.

The turner or blockmaker would spend hours at such a machine, pumping his foot up and down on the treadle. Steadiness, even when fatigued, was key when operating a lathe. Any wavering while holding the cutting tool could easily gouge the piece on the lathe. To aid the turner, treadle lathes were built with a seat consisting of a board "about two and an half Inches square, and the whole length of the Lathe." The "Workman places the upper part of his Buttocks against it, that he may stand the steadier to his Work, and consequently guide his Foot the firmer and exacter" upon the treadle (Moxon 1703:182). Steadiness also demanded that the entire lathe be very solidly built and all its joints snug. Blockmaking was fairly simple among the arts of turners, but it still required a trained eye and an experienced hand to construct a block that was both strong and balanced so that it may run smoothly and reliably.

Like all true craftsmen, a turner took pride in both his skills and his tools. The latter were absolutely essential to his trade and had to be well made and properly maintained. They also had to be suited to the craftsman using them, usually by wear over time, but also often by deliberate modification to ergonomically suit their user. Thus the craftsman and his tools were, in many respects, inseparable. It is therefore no surprise that craftsmen in English dockyards rose up in anger when the Navy Board attempted to declare that all tools to be used in the dockyards would be state property (R. V. Saville in Rodger 1984:97). An inventory of tools and equipment at the Stockholm navy yard in 1621 lists only a handful of miscellaneous tools in the 'blockmaker's cabin.' Included in the inventory are three handsaws, an auger, a gouge, and a scoring knife (*Riks Arkivet* 1621). All of these tools are used in the process of blockmaking, but the rest of the important gouges, calipers, and the most essential tool of all, the lathe, do not appear in the inventory. The inventory for the blacksmith's shop is also incomplete, listing only a few dozen hammers, tongs, and other implements, but no bellows or anvils (*Riks Arkivet* 1621). Although the 1621 inventory focused on general yard facilities, the lack of specialized or essential tools in the inventory of state property and the propensity of craftsmen to keep their own stock of tools strongly suggests that this may have been the case in the Stockholm navy yard. Using their own tools in the yard may have been at the craftsmens' request or perhaps the sub-contracting processes stipulated that the master craftsmen needed to supply all their own equipment. The *arrende* certainly required the chief contractor to obtain all materials and labor for the dockyard. The king would only supply funds (Cederlund 2006:40). Hybertsson may have taken a similar stance on the matter of procuring tools. It is certainly reasonable to conclude that many of the more specialized craftsmen did indeed own their own tools. If so, this granted them an extra margin of personal pride, investment, and at least a notion of autonomy.

Although the navy yard inventory is painfully short of tools for blockmaking, it is possible to reconstruct Mårten Jakobsson's tool collection and the production process. The 412 complete rigging and gun tackle blocks and 143 identifiable block parts and fragments raised with *Vasa* provide a sampling of his work large enough to reveal key patterns used in producing these small, simple, and yet essential machines. Many of the blocks recovered with *Vasa* are sufficiently well preserved to retain tool marks from the craftsmen in the Skeppsholmen turner's shop nearly four centuries ago. Chisel and drawknife cuts, bore holes, and concentric, circular lathe grooves can be found on nearly a third of the blocks in the collection.

In addition to the lathe, the process of making a block required a bare minimum of eleven hand tools including an axe, a keyhole saw, a larger handsaw, a block shell pattern, an auger, a rasp, a narrow chisel, calipers, a drawknife, and a spindle gouge. The archaeological evidence bears evidence of most of these tools. All of them, except perhaps the axe, were specialized tools. The lathe tools, in particular, were distinctive because of their unusual handles "not made as the Handles of Joyners or Carpenters Tools are, but tapering towards the end, and so long that the Handle may reach (when they use it) under the Arm-pit of the Work-man, that he may have more stay and steady management of the Tool" and so minimize vibration and chattering (Moxon 1703: 184). Although these long-handled tools are larger, they are only a few centimeters longer than a carpenter's chisel and can be hard to spot. They are shown in the treatises of both Joseph Moxon and David Steel (Figures 10.6 and 10.7).

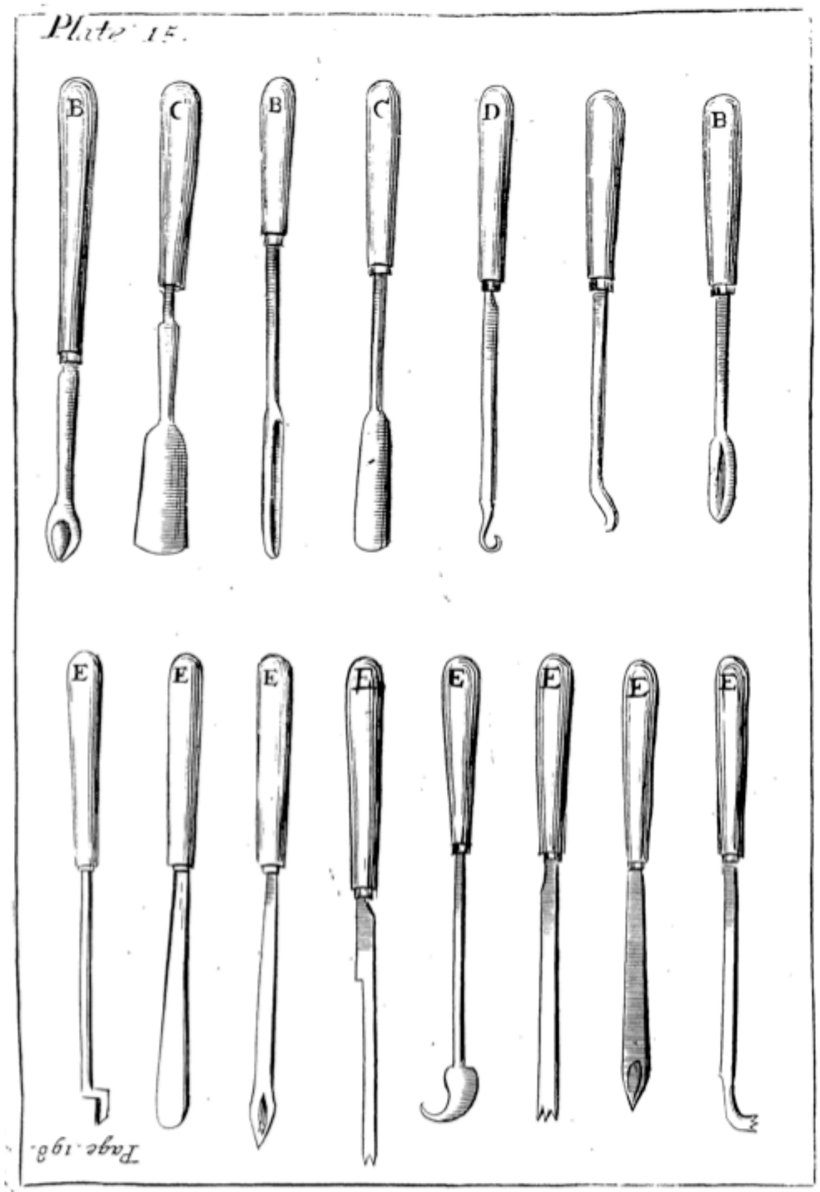


FIGURE 10.6. An assortment of 17th century turner's scrapers, chisels, and gouges. Most of these are types used for turning artistic pieces such as baroque furniture legs. The navy yard turner would have used a much smaller range of lathe tools (Engraving from Moxon 1703:198).

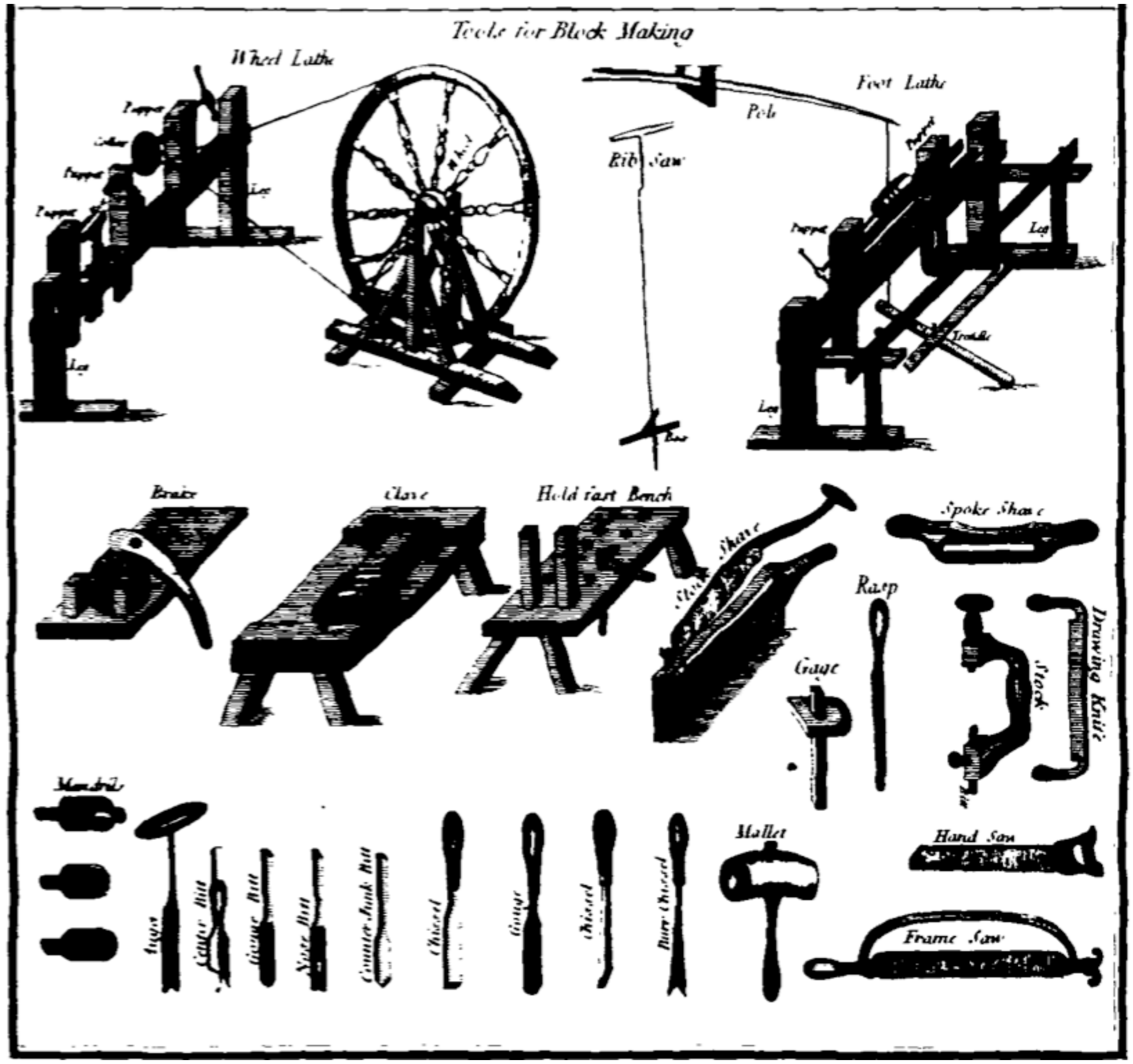


FIGURE 10.7. The blockmaker's tools including two types of lathes, a brake, clave, and hold-fast bench, stock shave, rasp, drawknife, gauge, brace, hand saw, frame saw, mallet, and an assortment of chisels, gouges, and scrapers (Engraving from Steel 1794b:Blocks Plate 2).

The larger tools in the turner's shop consisted of the lathe, three types of clamps, and a stock shave (Figure 10.7). The latter was a hinged chopping block resembling the large paper cutters found in office copy rooms today. It was used to rough-cut the block shells. The shells were then secured on the hold-fast bench, the free-standing clave, and the workbench-mounted blockmaker's brake while the shell was sawn to shape, bored and chiseled out, and then carved into a finished shell with a drawknife and given a strop score with a gouge. Moxon (1703) discusses these larger shop tools and their use in moderate detail.

Materials

Second to tools, the most important thing a craftsman has to work with is his raw material. In most naval yards, suppliers were contracted to obtain suitable timber and bring it to the yard. Shipwrights were often involved in this process, particularly in the selection of compass timber. Less specialized timber such as planking or wood for block shells was often simply purchased from timber merchants and delivered to the shipyard. An English master shipwright complained of the lumber supply in the Chatham Naval Dockyard in 1673, "we are now at such great a stop for want of provisions that we cannot employ one third part of our workmen we having not one piece of timber in the yard fit for the carrying on the works" (Pett 20 March 1673 in Rodger 1984: 117). Mårten Jakobsson's source of material is unclear. According to one English account, blocks were made from wood scraps sawed off from framing timbers (Cooper 1984:194). The *Vasa* blocks, however, do not reflect such scavenger behavior. Virtually every one of *Vasa*'s 412 blocks is cut from choice stock and only a handful feature blemishes in the wood, such as knots or twisted grain. Almost all of these are unusually large blocks wherein such deformities could not be avoided. The smaller blocks are all made of tight-, straight-grained wood cut from close to the heart of the timber. The oak block shells are almost exclusively quarter-sawn while the ash blocks are slab cut. Such selectivity and uniformity indicates that Mårten Jakobsson had considerable choice in the quality of the material he used. In all likelihood, Jakobsson's blockmaking material was probably carefully chosen by Henrik Hybertsson's brother, Arendt, who held the *arrende* for procuring materials and timber for the Stockholm navy yard (Hocker 2011:11). As evidenced by the *Vasa* block collection, Jakobsson required a sizable stock of ash and oak as well as a hardwood suitable for use as axles. The other items produced in the turner's shop, such as the parrels, pump plungers, and belaying pins, also had fairly strict materials requirements. Using an inappropriately soft, absorbent wood that swells when wet for making pump parts, for instance, could pose a significant problem for de-watering the ship. For the yard's specialized craftsmen, selectivity in choosing raw materials was as important as their skill in working that material.

Block Production

The process of producing a block can be divided into three operations, one for each of the three discrete parts of a block. The first step was to begin making the sheave. *Vasa*'s sheaves were cut from sections of ash plank stock of appropriate thickness with the pith running down the center of one face. A disc was sawn from a section of this planking using a handsaw and a circular pattern of the required diameter (e.g. 140mm for most of the *sub-type 1* single blocks). Next, the disc was mounted on the lathe between the pike and screw. Then the turner set to work. A pair of calipers and a parting tool were used to establish the proper thickness of the sheave. The parting tool was held to the faces near the rim, scoring deeper into the wood until it had marked the desired final thickness of the sheave. These depth gauge rings can still be seen on many of the *Vasa* block sheaves, appearing as two or three rings scored into the rim of the sheave faces (See Figure 6.5). These rarely appear more than 15mm from the edge of the sheave, as scoring closer to the centre was unnecessary and because setting the sheave thickness at the rim resulted in a more precisely centred and balanced end product. Excessive thickness in the middle portion of the sheave faces was split off with chisels. Several of the blocks (e.g. Fnr 19905) have clearly visible chisel marks on the sheave faces (Figure 10.8). These indicate that at least one of the chisels in Jakobsson's shop had a 43mm-wide tip.

FIGURE 10.8. Chisel marks on the face of a sheave. This sheave was thinned after turning as shown by the chisel marks on its face and the lack of depth gauge rings (Photo courtesy of the Vasa Museum).

Once the sheave's overall dimensions had been established, the blockmaker began working on the groove set into the circumference that would carry the fall (Figure 10.9). Cutting this groove, known as a cove in turners' parlance, is particularly difficult on a lathe as at least twice per revolution the cutting tool dug directly into the end-grain (Klenke 1954:38) (Figure 10.10). Mårten Jakobsson and his assistants had to have very sharp tools and steady hands to produce the sheaves without catching or gouging the soft ash wood. As little as 50 years later, block sheaves were primarily made of *lignum vitae* imported from the New World. This wood, although much harder, was easier to cut due to its tighter grain structure and the fact that they were always turned across the grain and never directly into it.

FIGURE 10.9. Vasa Museum carpenter Maria Eriksson scoring the face of a block sheave on a modern lathe to set the thickness of the finished sheave (Photo by Anneli Karlsson, 2007, courtesy of the Vasa Museum).

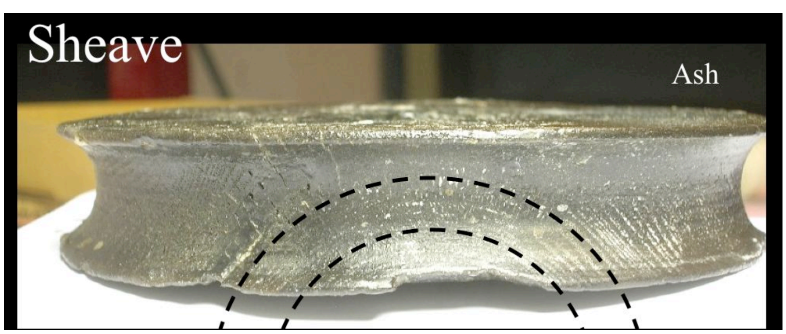


FIGURE 10.10. The dotted black lines follow the annular rings of the exposed end-grain in one of *Vasa*'s ash sheaves (Photo by Nathaniel Howe, 2007).

The sheaves for *Vasa* were almost certainly turned from a supply of fully dried stock. The manner in which they were cut very close to the centre of the trunk or limb such that the pith runs up one face of the sheave makes them very prone to warping during the drying process. Yet virtually none of *Vasa*'s block sheaves exhibit even minor warping, indicating that they were turned from wood that had already been dried and undergone any shrinkage and warping to be expected. The few that are warped are so severely disfigured that they could not rotate, or sometimes even fit, inside a block shell (e.g. Fnr 19919s and 15255). The severity of the warping and decayed condition of these sheaves indicates that these examples warped during conservation.

Once the sheave was finished, the blockmaker turned to the second phase of block production: the creation of the shell. First, a suitable piece of wood was selected with clear grain and oriented for maximum strength (slab-cut for ash; quarter-sawn for oak). An oval or elliptical template was placed over the broadest face of the piece of timber, traced, and then the shell was hewn or sawn to shape using the stock shave and a handsaw (Figure 10.11).

Analysis of the blocks recovered with *Vasa* and experiments at the Vasa Museum's woodshop by carpenter Maria Eriksson in 2007 suggest that the blockmaker then bored the axle hole through a solid block of wood (Figure 10.12). This had to be perfectly straight. If the axle was angled in any direction, the sheave would chafe against the inside of the block shell, which could cause it to jam, split, or, in an extreme case of prolonged high-strain usage, it could even catch fire (Cooper 1984:184).

FIGURES 10.11 and 10.12. Once a block of wood suitable for a shell is picked out (slab cut for ash, quarter-sawn for oak), the shape of the block is marked out using a pattern. Then the axle hole is bored through the center (Photos by Anneli Karlsson, 2007, courtesy of the Vasa Museum).

Then the shell was turned on edge and a series of holes were bored into the shell to demarcate the sheave mortise. These holes were bored roughly halfway through the width of the shell. Evidence in some of the sheave mortises indicates that the bits used in the Skeppsholmen shop were approximately 18-22mm in diameter (e.g. Fnr 08653). Once the series of bore holes was drilled, the shell was turned over and the same pattern of holes was bored in from the other side, the bore holes intersecting with the first set at the middle of the block (e.g. Fnr 08463). Finally, a small saw was used to clear out the material between the bore holes (Figures 10.13 and 10.14).

FIGURES 10.13 and 10.14. Sawing out the sheave mortise (Photos by Anneli Karlsson, 2007, courtesy of the Vasa Museum).

Then a chisel was used to smooth out the inside surfaces of the sheave mortise. Flat chisels ranging from 12-40mm and rasps were used to smooth the inside of the sheave mortise and a gouge was used to round out the swallow (Figure 10.15). The chiseling left a smooth surface in the mortise and clean edges across the interior openings of the axle holes.

FIGURE 10.15. Chiseling out the inside of the sheave mortise after boring more holes to clear out the shell (Photos by Anneli Karlsson, 2007, courtesy of the Vasa Museum).

A saw and the stock shave were used to take the corners off the shell and shape it according to the pattern traced on its face. Next, a drawknife was used to beard, or taper, the cheeks and to chamfer the edges of the shell to remove the sharp edges and prevent splitting as well as wear against the sails (Figure 10.16). The final step to prepare the shell was to use a half-round tipped gouge to cut strop scores into the cheeks for gripping the strop and securing the block to its pendant (Figure 10.17).

FIGURES 10.16 and 10.17. Chamfering the edges of the shell with a drawknife and then gouging out the strop scores (Photos by Anneli Karlsson, 2007, courtesy of the Vasa Museum).

How the shells were dried and cured is not clear. After more than three centuries of immersion in Stockholm harbor, wood surface erosion, and conservation treatments there is no evidence left on the blocks themselves to attest to the process. The oak-shelled blocks were most likely carved from freshly felled trees as green oak is easier to work than dried oak. To slow down and even-out the drying process in order to prevent splitting, oil or tar was probably applied to the shells. Whether the ash blocks were made from green wood or dried stock is harder to guess. Drying has considerably less impact on the workability of that species.

Once the shell was completed, the sheave was slid into the sheave mortise to test the fit. Any spots of binding were chiseled down to allow clearance. Then an un-tapered axle was cut to length from small diameter limbs or sapling trunks with the pith running directly up the centre. These were most likely juniper or hornbeam (Fred Hocker 2011, pers. comm.). The axle was finished off with a knife (e.g. Fnr 10577) to remove any remaining bark and give it a smooth, clean surface for the sheave to rotate on.

Then the three pieces of the block were assembled (Figure 10.18). The sheave was smeared with a greasy layer of tallow to lubricate it and then it was inserted into the mortise (Olof Pipping 2006, pers. comm.). The axle was then slid into place and pounded snugly into the shell, locking the block together (Figure 10.19). Lastly, a coat of oil or tar was applied to the shell and the block was delivered to the rigger's store. Once rigged, the strop would trap the ends of the axle in place.

FIGURES 10.18 and 10.19. All three parts of the block finished, checked for fit, and then assembled and the axle pounded snugly into place (Photos by Anneli Karlsson, 2007, courtesy of the Vasa Museum).

It is unknown how long it took Mårten Jakobsson or his assistants to complete the production of one block. During the two years *Vasa* was under construction, the block shop needed to produce at least 650 blocks to meet the needs of the ship's armament and rig. That works out to approximately one block per day, but manufacturing these 650 blocks had to be done in addition to the parrels, pumps, and belaying pins *Vasa* required as well as the needs of the other ships of the fleet calling at the Stockholm navy yard. After all, the all-wooden blocks made at the block shop did not have the longevity of those produced after the introduction of hardwood *lignum vitae* sheaves and metal bearings. The 30 blocks with cracked or split shells, shattered sheaves, and crushed axles found stowed in *Vasa*'s hold testify to that. Even if Mårten Jakobsson and his journeymen and apprentices turned out only one or two or three blocks per day, they were probably never able to stay much ahead of the needs of the fleet.

Chapter 11. Conclusion

Fully fitted-out, *Vasa* required over 630 rigging and gun tackle blocks to operate the ship's expansive rig and heavy armament. Another 100 spares were stowed below, ready to be pressed into service. Although blocks are relatively simple machines, they are absolutely essential to the operation of a large warship such as *Vasa*. Inherently capable of doing no more than allowing cordage to pass around sharp bends with minimal resistance, blocks have played an enormous role in the history of seafaring through this basic, but vital function. Since at least 300 B.C., blocks have made it possible to redirect and multiply pulling forces, granting ships' crews the mechanical advantage or angle of purchase necessary to load and maneuver their vessels. These fundamental functions were of unparalleled importance aboard *Vasa,* where blocks were employed all over the ship for everything from manipulating the rig and running out the guns to raising the anchor and loading provisions. No other single item of hardware played such a central role in the operations of the ship. Analysis of the 412 extant blocks and 143 loose fragments, their find locations, and comparative examples from across Europe have made it possible to draw a few conclusions regarding *Vasa* and the blocks carried onboard, 17th century rigging practices, and, ultimately, the men who worked with *Vasa*'s blocks, both in the turner's shop and aboard ship.

Beginning with the blocks themselves, this study shows that *Vasa*'s rigging and gun tackle blocks were generally simple, but made with care and attention to detail. Although not perfect, the blocks are relatively standardized, remarkably symmetrical in form, and all surfaces are smooth and cleanly finished. The sheaves are perfectly circular, uniform in thickness, and fitted to the axles and shells with little slop or play. All components are made from high quality materials and the evidence indicates that close attention was paid to grain direction and to ensuring that the sheaves and axles sat square to the sheave mortises. Tool marks on some of the better-preserved examples support these functional and formal observations. Depth gauge scores in the sheaves indicate close control of sheave thickness on the lathe and closely spaced chisel marks in areas requiring little refinement, such as the breech of the block shells, reflect special care in the final finishing.

This attention to detail was not merely aesthetic. As functional devices, clearances between the component parts, the quality of the materials, and their conversion from raw timber are all important factors in guaranteeing reliable service from a block. The most critical aspect of their manufacture is that the sheave and swallow diameters match the cordage diameters that will be used in order to avoid jamming and paralyzing the rig. Comparison of swallow diameters and other key dimensions in *Vasa*'s blocks show that they were made with a moderate level of standardization. The dimensions of the various parts were not as strictly controlled as in Nelson's navy, for example, but the degree of standardization in the *Vasa* block collection is certainly high enough to ensure that the blocks would reliably serve their purpose. The level of standardization, however, was not uniform for all parts of these blocks. The shells, for instance, show a relatively low level of standardization, the overall length often ranging by 10-30mm even though the shells were cut using patterns. The diameter of both the swallows and sheaves are consistent to within 3-5mm (among blocks intended for a common purpose), demonstrating a much higher level of standardization than in the shells. This discrepancy in standardization is easy to understand; sheave and swallow dimensions have much lower tolerances for error than overall shell size. As long as the shell is large enough to withstand the load, its exterior dimensions are more or less inconsequential. The swallow and sheave, however, must accommodate fast-moving, sized cordage with relatively low tolerances for clearance.

The dimensional consistency visible in the *Vasa* block collection is particularly interesting as such standardization in ships' fittings was still an evolving practice in the early 17th century. It had always been necessary to match rigging blocks to the cordage they would carry, but it never had to be applied at such an enormous scale. The need to standardize blocks had become significantly amplified in the years leading up to *Vasa*'s construction. One factor was the rapidly increasing complexity and size of ships and their rigs during the preceding century. Another factor was the replacement of armed merchantmen with purpose-built warships built and maintained in major naval bases and subject to the imposition of associated standards of construction and outfitting handed down from naval administration. This was particularly true in Sweden. By the time *Vasa* was built, uniformity and standardization had become central themes in the success of Gustav II Adolf's modernization reforms. These measures provided strategic, tactical, and organizational advantages. Uniform standards were applied to training, armaments, and field units. Centralized naval specifications, however, were still their infancy in the 1620s. Most consisted of little more than general proportions. Yet, as Swedish military production centers became more actively controlled by the Crown (sometimes via private contractors), more and more aspects of design and manufacturing processes were dictated from above (Glete 1993:44). Although the precise details for warship design were still largely left to the shipbuilder, individual aspects of construction and outfitting, such as armament, spar dimensions, cordage sizes, and rigging hardware, were being quickly regulated, allowing for greater interchangeability of equipment among ships and permitting more rapid outfitting (Glete 1993:47). This was absolutely necessary to keep costs down and to ensure that the ship's equipment was compatible and functional. By the mid-1620s, careful attention to standardization appears to have overtaken the turner's shop. Whether these standards were handed down from a central authority or if they still came in laterally from the riggers and ships' crews working in the yard, as in earlier generations, is impossible to say. By the late 18th century, the British Royal Navy was issuing exhaustive specifications for all blocks to be rigged on Royal Navy warships. These covered every aspect of their design from the selection of materials to the precise dimensions of every component. Ironically, this prodigious manifestation of central authority was driven by *de*centralization of production and the increased use of naval procurement contracts with commercial manufacturers for whom specifications and prices had to be listed in explicit detail (Steel 1794b:160).

The design and construction of *Vasa*'s blocks also provides insight into Sweden's use of block technology relative to other European seafaring nations in the early 17th century. If the few scattered archaeological collections available for comparison can be considered representative, the Swedish navy's use of block technology, as defined by *Vasa,* was roughly on par with most of the other large navies of Europe. The vast majority of the blocks were of all-wooden construction and only a few had sheaves or axles made of bronze or iron. None of the blocks were fitted with metal coaks or bearings of any kind and thus their efficiency and load capacity were accordingly limited. The efficiency of these wooden blocks, in particular, was impacted by the large contact interface between the sheave and the large-diameter wooden axle as well as the lack of bushings to prevent the sheave from shifting on the axle and chafing against the inside of the sheave mortise. Tallow smeared on the axles certainly helped, but rigging systems involving multiple sheaves were guaranteed to lose a significant percentage of the pulling force to friction more rapidly than blocks made of composite materials. This probably went largely unnoticed aboard *Vasa* as all-wooden blocks were by far the most common type. Yet, it may still have played a small, if largely inconsequential, role in *Vasa*'s short service life. In his testimony after the sinking, Lieutenant Petter Gierdsson reported that, as the ship began to flood, the sheets were cast off to spill the wind, but the breeze was not strong enough to pull the sheets through the blocks (Cederlund 2006:56). The lightness of the wind (still strong enough to heel the ship over) and the weight of the sailcloth were certainly the principal factors in this final misfortune, but resistance in the blocks appears to have been an additional factor.

By the 17th century, some seafaring nations had improved block technology by including more metal parts to reduce friction and thereby increase efficiency and longevity, but most navies did not make this transition until the 18th century. Virtually all of the blocks recovered from Red Bay, *Batavia*, *La Belle*, and *Santo Antonio De Tanna* were also made entirely of wood. According to the archaeological record, *Mary Rose*—lost in the Solent more than 75 years before *Vasa*—was one of the few ships fitted with a large number of bronze or iron sheaves. Swedish metallurgists were certainly capable of producing metal block parts and could do so at a reasonable price (Fred Hocker 2011, pers. comm.), but wooden sheaves were almost always sufficient for the task and were quick and inexpensive to manufacture. In the rare cases that a wooden block was not strong enough for the load, an iron block or two could be substituted easily enough (as exemplified by *Vasa*'s ram's head blocks and cat blocks). A generation after *Vasa* sank, many European navies began using *lignum vitae* imported from the New World as the material of choice for making sheaves. In the modern maritime industries of today, this wood species is still competitive with metal block sheaves.

The large quantity of blocks recovered with *Vasa* and the range of types represented provides important information about the rest of *Vasa*'s rig. Since *Vasa* was raised in 1961, it has been assumed that the ship carried a Dutch rig. This assertion has been largely accepted without opposition as *Vasa*'s hull is classically Dutch in its form and construction, it was built by a Dutchman working for the Swedish Crown, and Admiral Richard Clerke's contract for rigging *Vasa* stipulated that it be done in the "manner of the best Holland warships" (Riksarkivet 1626: Folio 107r (§ 4), lines 1-12). Examination of the placement of belaying points, bitts, and fairleads on *Vasa*'s weather deck has shown that the features of ship are consistent with the proportions and other details of Dutch rigging. The blocks also match the current understanding of Dutch rigging. While *Vasa*'s collection of *sub-type 1* single blocks are not significantly different than those found elsewhere, the assortment and quantity of specialized block types, such as the combined-topsail-sheet-and-lift block and the elongated upper lift blocks, matches the specialized types usually associated with Dutch rigging practices of the early 17th century. The presence of these blocks on *Vasa* strongly supports the current rigging reconstruction for *Vasa* built on the conclusion that the ship was Dutch-rigged. Moreover, the consistency between the specialized block forms found in association with *Vasa* and those seen in contemporary art and ship models from the Netherlands provides archaeological evidence and thus legitimacy for the concept of a distinctly Dutch method of rigging large ships of war.

The preponderance of evidence that *Vasa* carried a Dutch rig makes it possible to reconstruct its missing elements through historical research. Contemporary art and ship models provide a wealth of detailed information about every component and its placement in a Dutch rig. Based on these sources, approximately 75 blocks should have been fitted in the rigging of the mainmast, 100 for the foremast, 40 for the bowsprit and sprit topmast, and 43 for the mizzen. The gun tackles required another 284 blocks. All totaled, 542 blocks were required to fully outfit and operate the ship's rig and armament. Another 80 to 100 blocks stowed below as spares tops off *Vasa*'s anticipated complement of rigging and gun tackle blocks at approximately 630 blocks. The 412 intact blocks recovered, therefore, amount to 65% of the blocks that were probably on board when *Vasa* sailed. The 143 fragments represent perhaps another 10%. Averaging these figures yields an estimate of a roughly 70% survival rate for *Vasa*'s total complement of blocks. Although far from complete, the *Vasa* block collection is impressively large given the length of time the ship spent on the bottom and the fact that close to 60 blocks (almost 10%) were probably salvaged with the upper rig in 1628.

The 70% survival-rate for *Vasa*'s blocks, however, does not apply to all the ship's blocks equally. The topmast and topsail rigging, for instance, likely has little or no representation, while the ship's stock of spares stowed below is essentially complete and intact. Breaking down the major areas of block usage, the survival rates are 99% for the spares, 63% for the gun tackles, and 30% for the actual sailing rig *Vasa* carried on 10 August 1628.

Archaeology is effective at distilling details such as the total percentage of blocks left from the ship's rig, but its true purpose is to advance our knowledge of past cultures and the people living in them. Although a thesis on rigging blocks is somewhat prone to becoming preoccupied with mechanics of these mechanical devices and their usage in a complex rig, it is still possible to discern evidence of the men who manufactured this hardware and deduce certain aspects of their lives. Although the standardization of *Vasa*'s blocks and the materials in them reflect elements of Sweden's social organization and its resource base, it is largely through the tool marks and evident decisions of their maker, combined with historical records, that *Vasa*'s blocks carry information about the men who were associated with them.

More than anyone else, the block collection provides a glimpse of the Stockholm navy yard's master turner and blockmaker, Mårten Jakobsson. Despite a dearth of written sources about him and the Stockholm naval yard's blockmaking shop, it is still possible to reconstruct a remarkably illustrative understanding of his occupational environment. The kind of man he was and the sort of life he lived in the hours after the navy yard closed each night is probably impossible to know. Once he passed through the shipyard gates, he disappeared into the multitude of untraceable craftsmen and laborers working in Stockholm in the 1620s. Yet, what can be determined about his working environment is particularly fascinating. In this lone craftsman's surroundings, the transition from small independent centers of production to the institutionalization of traditional handicrafts under large, state-owned installations (operated by private contractors) is readily apparent. Jakobsson did not own his own shop or have to compete with fellow turners in the commercial market to attract customers. He worked under the direction of Henrik

Hybertsson and King Gustav II Adolf. Yet, in this early period of handicraft institutionalization, Jakobsson was able to continue to operate with much of the autonomy of an independent craftsmen, working with his own small collection of tools, hand-picked assistants, and personally selecting the best material available for his product.

In the decades and centuries to come, blockmaking changed entirely. In 1805, engineer Marc Isambard Brunel invented a mechanical blockmaking machine that entirely replaced the master craftsman. These machines constituted “the first instance in the world of the use of machine tools for mass-production” (Goad 1983:15). The installation of 45 blockmaking machines in the old block mill in the Portsmouth Naval Dockyard enabled the Royal Navy to discharge 110 blockmakers and hire ten machinists in their place. The new machines manufactured over 200 types of blocks, requiring only 75 seconds to carve and shape each shell. By 1808, they were producing over 1,400 blocks per day and 130,000 per year (Goad 1983: 81 & Cooper 1984: 206, 208). Brunel ultimately completed the institutionalization of the traditional craft of blockmaking under the modern, industrialized nation-state—a transition that was already in motion in *Vasa*’s time. Yet, for Mårten Jakobsson in the mid-1620s, blockmaking was a trade with a promising future offering stability and job security during the rise of the Swedish nation-state and the expansion of its modernized navy.

The men who manned and sailed the ships of the Swedish fleet left few tangible traces of their lives. Much of their experience must be derived from circumstantial evidence rather than direct record. It is only in this manner that the blocks contribute anything to the understanding of life onboard. For the men who handled the ship and wrestled with its unwieldy expanse of canvas, the block—particularly when rigged in tackles—was a precious ally. Blocks offered these sailors manifold increases in strength, improved angles of purchase, and could perform certain tasks aloft from a position on the deck. While warships of the 1620s were certainly fitted with more blocks than ever before, much of *Vasa*'s rig (and Dutch rigging in general) was still set up to rely on the brute strength of the crews. Based on the number of multi-sheaves blocks recovered, it appears there were far fewer tackles set up in *Vasa*'s rig than in subsequent generations. Extra advantage could be obtained by passing the working end of many of the lines around the capstan, but only one or two lines could be managed at a time by this method. Manpower was essential for sailing *Vasa*. Fortunately, that was not a problem. As sea battles were still primarily fought as boarding actions, hundreds of soldiers were stationed onboard and manpower was never in short supply. Such a multitude of available hands meant tackles were unnecessary for many of the smaller hauling operations such as raising the gunport lids or sheeting in the topsails. Moreover, aboard ship, putting men to work has always been a good way of keeping idle bodies out of mischief. Although *Vasa*'s sailors relied on their shipmates for assistance in hauling almost as often as they used tackles, the Swedish sailor aboard *Vasa* still benefitted from the hundreds of well-made, smooth-running blocks made by Mårten Jakobsson

References

Albenda, Pauline
1972 "A Syro-Palastinian (?) City on a Ninth Century B.C. Assyrian Relief." Bulletin of the American Schools of Oriental Research, No. 206 (April, 1972.pp. 42-48.

Anderson, R.C.
1927 *The Rigging of Ships in the Days of the Spritsail Topmast, 1600-1720*. Reprinted by Dover Publications Inc, New York, 1994. Originally printed by the Marine Research Society of Salem, Massachusetts.

Ashley, Clifford W.
1944 *The Ashley Book of Knots*. 1st edition. Doubleday Publishing Co. New York, New York.

Bass, George (editor)
2004 *Serçe Limani: An Eleventh-Century Shipwreck, Volume I, The Ship and Its Anchorage, Crew, and Passengers*. Texas A&M University Press, College Station, Texas.

Beach, Commissioner Richard
1984 "Commissioner Richard Beach to the Navy Board, 15 February 1672." *In The Naval Miscellany*, vol. 5, edited by N.A.M. Rodger, London, George Allen & Unwin for the Navy Records Society.

Biddlecombe, Capt. George
1848 *The Art of Rigging*, originally published by Charles Wilson, London, 1848. Reprinted by Edward W. Sweetman Company. New York, New York, 1979.

Block, Leo
2003 *To Harness the Wind: A Short History of the Development of Sails*. Naval Institute Press. Annapolis, Maryland.

Boyd, James E.
1921 *Mechanics: A Text-Book for Engineers*. 1st edition. McGraw-Hill Book Company, Inc. New York, New York.

Bradley, Charles S.
1980-81 *The Ship's Fittings' Rigging Components and Rope Recovered from the Wreck of* Le Machault. Microfiche Report Series 192. Quebec, Parks Canada.

Bradley, Charles S. (*cont'd*)
2007 Chapter "Rigging and Deck Hardware" in *The Underwater Archaeology of Red Bay: Basque Shipbuilding and Whaling in the 16th Century*. Edited by Robert Grenier, Marc-André Bernier, and Willis Stevens. Parks Canada. Ottawa, Ontario, Canada.

Brady, Edward
1967 *Tugs, Towboats, and Towing*. Cornell Maritime Press, Inc. Centreville, Maryland.

Casson, Lionel
1971 *Ships and Seamanship in the Ancient World*. Princeton University Press. Princeton, New Jersey.

1994 *Ships and Seafaring in Ancient Times*. University of Texas Press. Austin, Texas.

Cederlund, Carl Olof
1966 *Stockholms Skeppsgård 1605-1640*. Licentiate thesis, Stockholm University. Stockholm, Sweden.

1983 "The Old Wrecks of the Baltic Sea: Archaeological recording of the wrecks of carvel-built ships." *British Archaeological Reports, International Series* 186. Oxford, England.

2006 Vasa *I: The Archaeology of a Swedish Warship of 1628*, ed. Fred Hocker. Stockholm: Statens Maritima Museer. Stockholm, Sweden.

Chatterton, E. Keble
1923 *Ship-Models*, Studio Limited. London, United Kingdom.

Cooper, Carolyn C.
1984 "The Portsmouth System of Manufacture," Johns Hopkins University Press. *Technology and Culture*, vol. 25 no. 2 (April 1984), Baltimore, Maryland. p.182-225.

Corder, Catharine
2007 "*La Belle*: Rigging in the Days of the Spritsail Topmast, a Reconstruction of a Seventeenth-Century Ship's Rig." Masters thesis for Texas A&M University. College Station, Texas.

Glete, Jan
1993 *Navies and Nations: Warships, Navies, and State Building in Europe and America, 1500-1860,* vol. 1. Almqvist & Wiksell International. Stockholm, Sweden.

Goad, J. G.
1983 *Historic Architecture of the Royal Navy: An Introduction*. Victor Gollancz Ltd. London, United Kingdom.

Goldenberg, Joseph A.
1976 *Shipbuilding in Colonial America*. University Press of Virginia, 1976. Charlottesville, Virginia.

Green, Jeremy
1977 "Australia's Oldest Wreck: The Loss of the *Trial*, 1622." *British Archaeological Reports*, Supplementary Series 27. Oxford, England.

1989 "The loss of the *Verenigde Oostindische Compagnie retourschip BATAVIA,* Western Australia 1629: An excavation report and catalogue of artefacts." *British Archaeological Reports*, International Series 489. Oxford, England.

Hafström, Commander Georg
2006 "Salvage Attempts 1628-1683" in Vasa *I: The Archaeology of a Swedish Warship of 1628*, ed. Fred Hocker. Statens Maritima Museer. Stockholm, Sweden.

Harland, John
1984 *Seamanship in the Age of Sail: An Account of the Shiphandling of the Sailing Man-of-War 1600-1800, Based on Contemporary Sources*. Naval Institute Press. Annapolis, Maryland.

Heyman, Jacques
1972 *Coulomb's Memoirs on Statics: An Essay on the History of Civil Engineering*. Cambridge University Press. London, United Kingdom.

Hocker, Fred
2011 Draft 9 of Chapter 14 of *Vasa II*. Publication forthcoming from Statens Maritima Museer. Stockholm, Sweden.

2006 "Preface" to Vasa *I: The Archaeology of a Swedish Warship of 1628*, ed. Fred Hocker. Statens Maritima Museer. Stockholm, Sweden.

Hoving, A.B. & Cor Emke, translated by Richard Barker
2000 *The Ships of Abel Tasman*, Hilversum Verloren, Antwerp, Netherlands.

Kemp, Peter K.
1976 *The Oxford Companion to Ships and the Sea*. Oxford University Press. New York, New York.

Kirsch, Peter
1990 *The Galleon: The Great Ships of the Armada*. Naval Institute Press. Annapolis, Maryland.

Kipping, Robert
1854 *Rudimentary Treatise on Masting, Mast-making, and Rigging of Ships: Also tables of spars, rigging, blocks, chain, wire, and hemp ropes relative to every class of vessels.* Published by John Weale. London, England.

Klenke, William
1954 *The Art of Woodturning*. Charles A. Bennett Co. Peoria, Illinois.

Knutsson, Johann and Bengt Kylsberg
1989 "Svarvare" in *Hantverk I Sverige*. Edited by Bengt Nyström, Arne Biörnstad, and Barbro Bursell. AB Boktryk, 1989. Helsingborg, Sweden. pgs 303-310.

Krigs Arkivet (The Swedish War Archive)
1621 Svarvarstugan (Turner's shop) *Arkliräkenskaper* 1621. Stockholm, Sweden.

Laessøe, Jørgen
1953 "Reflexions on Modern and Ancient Oriental Water Works." *Journal of Cuneiform Studies*, Vol. 7, No. 1 (1953). Published by the Baghdad School of the American Schools of Oriental Research.

Lees, James
1979 *The Masting and Rigging of English Ships of War:1625-1860*. Conway Maritime Press, Ltd. London, England.

Lever, Darcy
1808 *A Young Sea Officer's Sheet Anchor*. Published by Longman, Hurst, Rees, and Orme. London, England.

Levinson, Irving J.
1961 *Introduction to Mechanics*. 2nd Edition. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Marquardt, Karl Heinz
1986 *Eighteenth-century Rigs and Rigging*, Phoenix Publications Inc of Cedarburg, WI, 1992. First published in German by Hinstorff Verlag GmbH in 1986, then translated to English in 1992. British edition published by Conway Maritime Press Ltd of London. U.S. edition published by Phoenix Publications, Inc.

Marsden, Peter and Richard Endsor
2009 Chapter "Propulsion" in Mary Rose, *Your Noblest Shippe: Anatomy of a Tudor Warship*, Volume 2. The Mary Rose Trust Ltd. Portsmouth, England.

Marsden, Peter
1974a "The County Hall ship, London." *International Journal of Nautical Archaeology* (1974) 3.1. Institute of Nautical Archaeology. College Station, Texas. pp.55-65.

1974b *The Wreck of the Amsterdam*. Hutchinson Publishing. London, United Kingdom.

Matthews, Sheila
2004 Chapter "Evidence for the Rig in the *Serçe Limanı* Ship*" in Serçe Limanı: An Eleventh-Century Shipwreck, Volume I, The Ship and Its Anchorage, Crew, and Passengers*. Edited by George F. Bass. Texas A&M University Press, College Station, Texas.

McGrail, Seán
2001 *Boats of the World: From the Stone Age to Medieval Times*. Oxford University Press. Oxford, United Kingdom.

Moxon, Joseph
1703 *Mechanick Exercises: or the Doctrine of Handy-Works*. Rose and Crown. London, United Kingdom.

Murphy, John M. and William N. Jeffers
1849 *Nautical Routine and Stowage; with Short Rules in Navigation*. Published by Henry Spear. New York, New York.

Nance, Morton R.
1949 *Sailing-Ship Models; A selection from European and American collections,* Halton & Company Limited. New York, New York.

Needham, Joseph
1965 *Science & Civilization in China*. Cambridge University Press. Cambridge, United Kingdom.

Nelson, E.W., C. L. Best, and W.G. McLean
1998 *Engineering Mechanics: Statics and Dynamics*. 5th Edition. Schaum's Outline Series. McGraw-Hill Publishing. New York, New York.

Neyland, Robert S. and Birgit Schröder
1996 *A late seventeenth century Dutch freighter wrecked on the Zuiderzee. Excavation Report 20*. Nederlands Instituut voor Scheeps- en onderwaterArcheologie / ROB (NISA). Lelystad, Netherlands.

Oleson, John Peter
1983 "A Roman Sheave Block From the Harbor of Caesarea Maritima, Isreal." *International Journal of Nautical Archaeology* (1983) 12.2. Institute of Nautical Archaeology. College Station, Texas. pp. 155-170.

Ossowski, Waldemar (editor)
2008 *The* General Carleton *Shipwreck*, *1785*. Polish Maritime Museum. Gdańsk, Poland.

Pastor, Xavier
1992 *The Ships of Christopher Columbus: Santa Maria, Niña, Pinta*. Anatomy of the Ship Series. Conway Maritime Press. London, United Kingdom.

Peterson, Gary Dean
1985 *Warrior Kings of Sweden: The Rise of an Empire in the Sixteenth and Seventeenth Centuries*. McFarland and Company, Inc. Jefferson, North Carolina.

Pett, Phineas,
1673 "Phineas Pett, Master Shipwright at Chatham, to the Navy Board, 4 March 1673," in in *The Naval Miscellany*, vol. 5, ed. N.A.M. Rodger (London, George Allen & Unwin for the Navy Records Society, 1984), p.116.

Pett, Phineas,
1673 "Phineas Pett, Master Shipwright at Chatham, to the Navy Board, 20 March 1673." In *The Naval Miscellany*, vol. 5, edited by N.A.M. Rodger (London, George Allen & Unwin for the Navy Records Society, 1984, p.117. Crow's Nest, New South Wales, Australia.

Riks Arkivet (Swedish National Archives)
1626 Financial records, Contract book 1626, folios 106-109. Stockholm, Sweden.

Roberts, Michael
1953 *Essays in Swedish History*. University of Minnesota Press. Minneapolis, Minnesota

Rule, Margaret
1982 *The* Mary Rose: *The Excavation and Raising of Henry VIII's Flagship*. Conway Maritime Press. London, United Kingdom.

Rålamb, Åke Classon
1691 *Skeps Bygerij eller Adelig Öfnings Tionde Tom*. Stockholm, Sweden.

Saville, R. V.
1984 "The Management of the Royal Dockyards 1672-1678," in *The Naval Miscellany*, vol. 5, edited by N.A.M. Rodger, 94-99. London, George Allen & Unwin for the Navy Records Society. Crow's Nest, New South Wales, Australia.

Steel, David
1794a *Elements of Mastmaking, Sailmaking, and Rigging,* originally published in 1794, reprinted in 1982 by Edward W. Sweetman Co., Largo, Florida.

1794b *The Elements and Practise of Rigging and Seamanship.* Vol.1. Published by David Steel. London, United Kingdom.

1797 *The Art of Making Masts, Yards, Gaffs, Booms, Blocks, and Oars, as Practised in the Royal Navy and According to the Most Approved Methods in the Merchant-Service.* Printed for David Steel by unknown printer. London, United Kingdom.

Stolt, Eva Marie & Fred Hocker
1981 *Vasa* Rigging Reconstruction by Stolt 1981, revised by Hocker 2006. Stockholm, Sweden.

Thompson, Bruce
1988 "The Rigging of a Seventeenth-Century Frigate at Mombasa, Kenya." Masters thesis for Texas A&M University. College Station, Texas.

Toss, Brion
1997 *The Complete Rigger's Apprentice: Tools and Techniques for Modern and Traditional Rigging.* 1st ed. International Marine/Ragged Mountain Press, Camden, Maine.

Unger, Richard W.
1978 *Dutch Shipbuilding Before 1800*. Van Gorcum. Amsterdam, Netherlands.

Ucelli, Guido
1950 *La Navi De Nemi*. La Libreria Dello Stato. Rome, Italy.

Vinson, Steve
1994 *Egyptian Boats and Ships*. Shire publications. Buckinghamshire, United Kingdom

Wells, H.G.
1920 *The Outline of History*. Garden City Publishing Co., Inc. Garden City, New York.

Winter, Heinrich
1967 *Der holländische Zweidecker von 1660/1670*, Delius, Klasing & Co, Bielefeld and Berlin, West Germany.

Witsen, Nicolaas
1690 *Architectura navalis et regimen nauticum: Aeloude en hedendaegsche scheepsbouw en bestier*. 2nd edition. Amsterdam, Netherlands.

Appendix

The Appendix of this thesis consists of tables containing essential data on all blocks and fragments organized by general find location (deck) and Find Number.

Blocks Found on the Weather Deck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
03016	pendant block	9	42	ash	484	SB	1-2	300
03049	sheave	NA	NA	NA	xx	x	1-2	4
10349	sheave fragment	NA	NA	NA	164	BB	x	x

Table Appendix.1. Table of blocks found on the weather deck and their locations.

Blocks Found on the Upper Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
03207	single block	1	35	oak	230	SB	x	x
03300	single block	1	36	oak	226	SB	9-10	x
03301	double block	1	32	oak	227	SB	8-9	x
03460	double block	1	35	oak	240	BB	8-9	x
03461	single block	1	33	oak	211	BB	8	x
03528	double block	1	33	oak	228	BB	13-14	2300
03529	double block	1	34	oak	222	BB	13-14	2300
03530	single block	1	32	oak	213	BB	13-14	2300
03656	single block	1	90	birch	480	BB	15	
03657	single block	1	34	ash	238	BB	15	2700
03664	single block	1	37	oak	246	MS	14-15	x
03666	double block	1	35	oak	247	BB	14-15	2500-2700
03670	single block	7	55	oak	445	BB	15-16	2500-2700
03741	lift block	5	39	ash	424	SB	14-15	2700
03748	single block	1	35	oak	223	SB	27	x
03757	double block	1	33	oak	233	SB	x	x
03790	double block	1	33	oak	245	SB	18-19	x
03848	double block	1	32	oak	215	BB	15-16	2700-2900
03849	single block	1	33	oak	230	BB	x	x
03912	double block	1	32	oak	238	SB	16	28.5
03962	single block	1	36	ash	245	BB	16-17	x
03987	double block	1	33	oak	228	SB	17-18	3000-3100
04017	single block	1	unknown	oak	179	SB	18	3100-3200
04024	double block	1	33	oak	216	SB	17-18	x
04078	single block	6(hook)	62	ash	460	BB	20	x
04124	double block	1	34	oak	238	BB	18-21	x
04125	single block	1	39	oak	249	BB	18-21	x
04126	single block	1	33	oak	216	BB	18-21	x
04134	single block	A-3	38	ash	236	BB	18-21	x
04147	fragment	G	28	oak	194	BB	18-21	x
04154	single block	1	31	ash	212	BB	19-21	x
04155	double block	1	30	oak	212	SB	19-21	x
04178	double block	1	28	oak	202	BB	19-21	x
04195	single block	1	37	oak	240	BB	19-21	x
04205	single block	1	44	ash	307	BB	10-14	x
04346	single block	1	37	ash	251	xx	7-14	x
04347	single block	1	34	oak	218	xx	7-14	x
04348	toplänteblock	5	34	ash	433	xx	7-14	x
04729	dead block	2	18	ash	83	SB	27	x
05132	sheave fragment	1	NA	NA	68	SB	2-3	x
05407	single block	6	39	ash	230	xx	21-24	x
05565	sheave	1	NA	NA	xx	x	22-23	x
05567	fragment	NA	unknown	ash	166	xx	22-23	x
05568	sheave fragment	1	NA	NA	130	x	22-23	x
05616	dead block	2	57	ash	149	xx	22-23	x
05621	fragment	NA	unknown	?	114	x	22-23	x
05622	fragment	NA	NA	NA	135	x	22-23	x
06467	sheave fragment	1	NA	ash	84	BB	24-26	x

Table Appendix.2. Table of blocks found on the upper gundeck and their locations.

Blocks Found on the Upper Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
06808	fragment	NA	unknown	?	138	BB	22-24	x
06860	fragment	NA	unknown	ash	129	BB	24-26	x
06984	sheave	1	NA	NA	xx	BB	22-24	x
06985	fragment	NA	unknown	ash	201	BB	22-24	x
07019	fragment	NA	unknown	?	130	BB	22-24	x
07086	sheave and axle	1	NA	NA	xx	BB	22-24	x
07118	single block	1	35	oak	236	BB	22-24	x
07134	fragment	NA	unknown	?	151	BB	22-24	x
07143	single block	1	25	ash	145	BB	22-24	x
07207	fragment	NA	unknown	ash	97	BB	22-24	x
07580	fragment	NA	unknown	oak	144	SB	22-24	x
07586	double block	1	30	oak	215	SB	1-3	x
07587	sheave	3	NA	NA	xx	BB	2	x
07588	double block	1	33	oak	222	SB	3	x
07658	double block	1	32	oak	239	SB	13-14	x
07659	single block	1	36	oak	235	SB	13-14	x
07660	single block	1	35	oak	221	SB	13-14	x
07688	single block	2	unknown	ash	256	SB	13-14	x
07701	double block	1	31	oak	217	BB	6-7	x
07703	double block	1	31	oak	219	BB	6	x
07752	sheave	1	NA	NA	xx	BB	3-4	x
07753	fragment	NA	33	oak	232	BB	6	x
07755	double block	1	34	oak	228	BB	3-4	x
07756	single block	1	29	oak	210	BB	3-4	x
07759	dead block	2	36	ash	166	BB	3-4	x
07801	fragment	NA	unknown	ash	151	BB	22-24	4000
07808	fragment	NA	unknown	?	156	BB	22-24	x
07852	single block	1	33	ash	221	BB	1-2	x
07859	single block	1	36	ash	224	SB	2	x
07889	single block	6	38	ash	269	SB	2	x
07890	double block	1	38	oak	210	SB	2	x
07921	single block	1	41	oak	223	SB	2	x
08008	ram's head block	NA	60	oak	962	x	3	x
08163	single block	1	34	ash	211	SB	x	x
08165	single block	1	unknown	oak	198	MS	x	x
08166	fragment	NA	unknown	oak	222	MS	x	x
08167	single block	1	unknown	ash	172	MS	3	x
08181	single block	1	30	oak	220	SB	1-3	520-695
08191	single block	1	42	oak	243	BB	1-2	x
08192	double block	1	33	oak	243	BB	1-2	x
08193	double block	1	31	oak	240	BB	0-2	x
08194	single block	1	36	oak	216	BB	0-2	x
08386	single block	8	44	ash	298	SB	23-24	x
08387	sheave	2	NA	NA	xx	SB	23-24	x
08388	sheave	2	NA	NA	xx	SB	23-24	x
08389	single block	1	35	ash	248	SB	23-24	x
08390	single block	1	unknown	ash	216	SB	23-24	x
08419	fragment	NA	unknown	oak	125	SB	2-3	x

Table Appendix.2 (*cont'd*). Table of blocks found on the upper gundeck and their locations.

Blocks Found on the Upper Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
08427	axle	NA	NA	NA	xx	MS	4-5	x
08449	sheave fragment	NA	NA	?	110	BB	1-2	x
08451	double block	1	32	oak	211	MS	21	x
08508	fragment	NA	unknown	ash	153	SB	23-24	x
08522	single block	1	32	oak	217	SB	23-24	x
08555	axle	G	NA	NA	xx	BB	1-2	x
08612	sheave	1	NA	NA	xx	BB	2-3	x
08613	single block	1	39	ash	287	BB	2-3	x
08614	single block	1	35	oak	203	BB	2-3	x
08651	double block	1(hook)	34	ash	282	BB	3-4	x
08652	single block	1	35	ash	218	BB	3-4	x
08653	double block	1	31	oak	208	BB	3	x
08688	single block	1	34	ash	204	BB	3-4	x
08689	double block	1	31	oak	215	BB	3-4	x
08692	snatch block	11	72	oak	832	MS	3-4	x
08696	fragment	NA	unknown	?	213	BB	3	x
08697	sheave	1	NA	NA	xx	BB	3-4	x
08758	sheave fragment	NA	NA	NA	85	BB	1-2	x
08759	fragment	NA	unknown	oak	214	BB	1-2	x
08799	fragment	NA	unknown	?	204	BB	1-3	x
08800	sheave fragment	NA	NA	NA	126	BB	1-3	x
08838	fragment	NA	unknown	oak	134	SB	3	x
08893	single block	1	31	oak	205	SB	5-6	x
08941	sheave	2	NA	NA	xx	SB	5-6	x
08982	single block	1	40	ash	262	SB	6-7	x
09149	single block	6(hook)	65	ash	543	BB	11-12	x
09198	double block	1	31	oak	245	SB	8-9	x
09346	single block	1	36	oak	211	BB	13-14	x
09350	double block	1	36	oak	235	BB	13-14	x
09501	single block	1	35	ash	226	BB	14-15	x
09502	single block	1	34	oak	215	BB	x	249-272
09509	single block	1	35	oak	231	BB	14-15	x
09550	double block	1	33	oak	222	BB	14-15	x
09611	single block	1	40	oak	243	BB	15-16	x
09637	single block	1	32	ash	217	BB	15-16	x
09638	double block	1	32	oak	199	BB	15-16	x
09647	single block	1	31	oak	240	BB	15-16	
09769	double block	1	33	oak	237	SB	15-16	x
09843	ram's head block	NA	50	ash	1015	BB	14-15	x
09901	double block	1	33	oak	220	BB	17-18	x
09902	double block	1	34	oak	204	BB	17-18	x

Table Appendix.2 (*cont'd*). Table of blocks found on the upper gundeck and their locations.

Blocks Found on the Upper Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
09928	single block	1	34	oak	192	BB	19-20	x
09958	fragment	NA	unknown	oak	170	BB	18-19	x
09972	double block	1	34	oak	236	BB	19-20	x
10001	single block	1	unknown	oak	181	SB	18-19	x
10054	sheave	2	NA	NA	xx	BB	20-21	x
10079	double block	1	unknown	oak	214	BB	21-22	x
10122	fragment	NA	unknown	oak	151	SB	22-24	x
10165	single block	1	30	ash	224	BB	21-22	x
10179	single block	1	33	ash	220	BB	21-22	x
10180	double block	1	37	oak	239	BB	21-22	x
10521	single block	2	39	ash	262	SB	23-24	x
10522	single block	1	29	ash	196	SB	22-23	x
10527	single block	1	32	ash	182	SB	23-24	x
10528	single block	1	49	ash	234	SB	22-23	x
10551	double block	1	34	oak	230	BB	22-23	x
11069	fragment	NA	unknown	ash	144	BB	x	x
11130	single block	1	32	ash	206	BB	13-14	x
3236a	single block	6	69	ash	398	SB	x	x
3236b	sheave and axle	NA	NA	NA	xx	SB	x	x

Table Appendix.2 (*cont'd*). Table of blocks found on the upper gundeck and their locations.

Blocks Found on the Lower Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
00416	double block	1	30	oak	233	akt	x	x
04915	block fragment	NA	unknown	ash	109	BB	27	x
05029	double block	1	32	oak	213	SB	0-1	x
05074	double block	1	unknown	oak	229	BB	0-1	x
05085	block fragment	NA	unknown	oak	213	BB	0-1	x
05087	double block	1	34	oak	239	SB	0-1	x
07702	single block	1	35	oak	225	BB	5-6	x
07710	single block	1	36	oak	247	BB	7-12	x
07714	single block	2	24	ash	151	BB	x	x
08452	single block	1	32	oak	210	MS	22	x
08454	single block	1	32	oak	201	MS	21	x
08455	single block	1	33	oak	201	MS	21	x
08456	double block	1	33	oak	223	MS	22	x
08457	single block	1	36	ash	227	MS	22	x
08459	single block	1	33	oak	201	MS	21	x
08463	double block	1	35	oak	236	BB	22	x
08788	single block	1	23	oak	151	xx	21	
10554	double block	1	34	oak	221	BB	22-23	x
10569	single block	1	37	oak	242	BB	20-21	x
10577	double block	1	32	oak	245	BB	18-19	x
10578	single block	1	32	oak	206	BB	18-19	x
10579	single block	1	32	oak	210	BB	26-27	x
10585	single block	1	33	oak	220	BB	18-19	x
10586	double block	1	33	oak	210	BB	18-19	x
10589	sheave fragment	3	NA	?	51	BB	18-19	x
10597	single block	1	41	ash	227	BB	26-27	x
10600	double block	1	33	oak	191	BB	16-17	x
10719	double block	1	34	oak	232	BB	25-26	x
10813	double block	1	33	oak	227	BB	16-17	x
10814	single block	1	32	oak	220	BB	16-17	x
10883	double block	1	33	oak	228	BB	14-15	x
10884	single block	1	36	oak	224	BB	14-15	x
10923	ram's head block	2	73	ash	875	BB	11	x
11055	single block	1	33	oak	205	SB	24-25	x
11056	double block	1	34	oak	222	BB	24-25	x
11098	single block	1	32	oak	217	BB	24	x
11107	double block	1	33	oak	223	BB	14-15	x
11108	single block	1	32	ash	228	BB	14-15	x
11115	single block	1	36	oak	240	BB	13-14	x
11134	double block	1	30	oak	215	BB	13-14	x
11135	double block	1	32	oak	202	BB	13-14	x
11169	double block	1	35	oak	241	SB	22-23	x
11170	single block	1	35	oak	222	SB	22-23	x
11171	double block	1	32	oak	194	SB	22-23	x
11172	sheave fragment	F-1	NA	NA	128	SB	22-23	x
11190	double block	1	32	oak	241	SB	21-22	x
11197	double block	1	unknown	oak	212	SB	21-22	x
11198	single block	1	33	oak	220	SB	21-22	x
11271	single block	1	unknown	oak	204	SB	20-21	x

Table Appendix.3. Table of blocks found on the lower gundeck and their locations.

Blocks Found on the Lower Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
11294	sheave fragment	F-1	NA	NA	124	SB	21-22	x
11305	double block	1	33	oak	226	BB	11-12	x
11327	single block	1	37	oak	208	BB	10-11	x
11341	double block	1	33	oak	218	BB	9-10	x
11404	double block	1	32	oak	225	SB	20-21	x
11421	block fragment	NA	NA	oak	63	SB	18-19	x
11429	single block	1	36	oak	209	SB	18-19	x
11430	double block	1	35	ash	210	SB	18-19	x
11468	double block	1	34	oak	222	BB	6-7	x
11474	double block	1	32	oak	227	BB	5-6	x
11481	axle	NA	NA	NA	xx	BB	5-6	x
11483	single block	1	32	oak	208	BB	11-12	x
11550	single block	1	34	oak	216	SB	18-19	x
11551	double block	1	31	oak	213	SB	18-19	x
11594	single block	1	39	oak	216	BB	3-4	x
11596	double block	1	33	oak	242	BB	2-3	x
11597	single block	1	33	oak	220	BB	2-3	x
11598	single block	1	33	ash	219	BB	2-3	x
11624	double block	1	32	oak	222	BB	2-3	530-677
11642	block fragment	NA	unknown	oak	193	BB	1-2	x
11645	single block	1	32	oak	222	BB	1-2	x
11658	dead block	2	34	ash	167	MS	5-6	
11659	single block	1	43	ash	276	MS	5-6	x
11729	block fragment	NA	unknown	oak	182	BB	0-1	x
11782	single block	4	48	ash	486	SB	10-11	x
12322	double block	1	35	oak	214	SB	16-17	x
12323	double block	1	32	oak	222	SB	16-17	x
12324	single block	1	36	ash	210	SB	16-17	x
12336	single block	1	33	oak	212	SB	15-16	x
12479	double block	1	35	oak	217	SB	14-15	x
12523	single block	1	31	oak	222	SB	14-15	x
12524	single block	1	33	oak	217	SB	14-15	x
12525	double block	1	31	oak	199	SB	14-15	x
12544	single block	1	unknown	oak	196	SB	13-14	x
12545	double block	1	33	oak	215	SB	13-14	x
12590	double block	1	32	oak	213	SB	13-14	x
12591	single block	1	36	oak	230	SB	13-14	x
12771	sheave	1	NA	NA	xx	SB	10-11	x
12884	treble block	1	55	oak	483	x	11-12	x
12885	double block	2	48	oak	481	x	11-12	x
12889	single block	1	33	ash	202	SB	9-10	x
12890	double block	1	34	oak	213	SB	9-10	x
13375	double block	1	33	oak	208	SB	9-10	1590-1750
13391	single block	1	34	ash	210	SB	8-9	1449-1590
13392	double block	1	34	oak	220	SB	8-9	1449-1590
13393	single block	1	36	ash	222	SB	8-9	1449-1590
13396	double block	1	31	oak	222	SB	8-9	1449-1590
13586	single block	1	35	oak	216	SB	8-9	1448-1590
13713	double block	1	28	oak	201	SB	10-11	1750-1906

Table Appendix.3 (*cont'd*). Table of blocks found on the lower gundeck and their locations.

Blocks Found on the Lower Gundeck

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
13714	single block	1	33	oak	221	SB	10-11	1750/1906
13729	double block	1	33	oak	231	SB	7-8	1302-1449
13743	single block	1	32	oak	191	SB	7-8	1302-1449
13744	double block	1	31	oak	199	SB	6-7	997-1302
13745	single block	1	unknown	oak	222	SB	5-6	997-1302
13746	double block	1	36	oak	240	SB	5-7	997-1302
13859	single block	1	unknown	oak	205	SB	5-6	997-1148
13878	single block	1	33	oak	217	SB	3-5	677-997
13887	double block	1	32	oak	204	SB	3-4	677-857
13888	single block	1	30	oak	185	SB	3-4	677-857
14017	double block	1	32	oak	216	SB	3-4	677-857
14098	double block	1	32	oak	223	SB	2-3	530-677
14099	single block	1	30	oak	209	SB	2-3	530-677
14610	double block	1	34	oak	236	SB	1-2	378-530
14611	single block	1	32	oak	184	SB	1-2	378-530
14801	single block	1	34	oak	248	BB	4-5	857/997
14866	sheave	1	NA	NA	xx	MS	x	0-530

Table Appendix.3 (*cont'd*). Table of blocks found on the lower gundeck and their locations.

Blocks Found on the Orlop

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
04980	block del	NA	unknown	ash	108	BB	27	x
14586	single block	1	30	ash	227	BB	19-20	x
14587	single block	1	35	ash	236	BB	19-21	x
14588	single block	1	33	ash	205	BB	19-21	x
17930	single block	4	43	ash	423	SB	23	3904
17945	single block	1	35	oak	230	BB	22-23	3757-3904
17987	single block	1	35	oak	232	SB	21-22	3587-3757
17992	single block	1	unknown	oak	180	BB	20	3435
17996	single block	1	30	oak	217	MS	18-19	3137-3283
18628	single block	2	35	ash	387	BB	21-22	3587-3757
18719	single block	1	39	oak	207	SB	7-8	1294-1449
18778	single block	1	30	oak	194	BB	22-23	3757-3904
18869	dead block	2	51	ash	217	BB	19-20	3283-3435
18870	dead block	3	33	oak	168	BB	19-20	3283-3435
18871	single block	1	32	oak	208	BB	19-20	3283-3435
18872	single block	1	31	ash	202	BB	19-20	3283-3435
18873	sheave	1	NA	NA	xx	BB	19-20	3283-3435
18878	single block	1	31	oak	186	BB	19-20	3283-3435
18879	single block	1	27	oak	201	BB	19-20	3283-3435
18880	dead block	2	42	ash	204	BB	12-13	2067-2214
18901	lift block	5	33	ash	336	BB	19-20	3283-3435
18902	dead block	1	40	ash	250	BB	19-20	3283-3435
18903	dead block	2	41	ash	215	BB	19-20	3283-3435
18904	skotblock	4	31	ash	637	BB	19-20	3283-3435
18905	single block	1	32	oak	218	BB	19-20	3283-3435
18906	double block	1	34	ash	240	BB	19-20	3283-3435
18908	long tackle block	4	32	ash	588	BB	19-20	3283-3435
18909	dead block	2	49	oak	259	BB	19-20	3283-3435
18910	single block	1	35	ash	217	BB	19-20	3283-3435
18911	single block	1	28	ash	195	BB	19-20	3283-3435
18917	sheave	1	NA	NA	xx	BB	19-20	3283-3435
18982	long tackle block	4	32	ash	602	BB	19-20	3283-3435
18983	dead block	2	40	ash	241	BB	19-20	3283-3435
18984	dead block	2	51	ash	202	BB	19-20	3283-3435
18985	single block	1	33	oak	229	BB	19-21	3283-3435
18986	single block	1	30	oak	216	BB	19-20	3283-3435
18987	single block	1	31	oak	206	BB	19-20	3283-3435
19198	single block	1	35	oak	188	SB	23	3904
19234	skotblock	4	35	ash	654	SB	23-24	3904-4049
19250	single block	1	32	oak	185	SB	23-24	3904-4049
19362	double block	1	36	oak	244	MS	23-24	3904-4049
19365	fiddle block	3	52	oak	679	BB	23-24	3904-4049
19429	single block	1	30	oak	193	SB	23	3904
19440	single block	1	30	oak	192	BB	25-26	4211-4370
19713	dead block	2	38	ash	175	BB	22-23	3757-3904

Table Appendix.4. Table of blocks found on the orlop and their locations.

Blocks Found on the Orlop

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
19716	single block	1	28	oak	225	BB	22-23	3757-3904
19717	lift block	5	28	ash	365	BB	22-23	3757-3904
19722	single block	1	30	ash	202	BB	22-23	3757-3904
19723	single block	1	35	oak	218	BB	22-23	3757-3904
19741	dead block	2	38	ash	182	BB	23	3904
19742	single block	1	31	oak	192	BB	23	3904
19746	single block	1	31	oak	196	BB	23	3904
19901	single block	1	30	oak	221	BB	22-23	3757-3904
19902	single block	1	32	oak	212	BB	22-23	3757-3904
19903	single block	1	32	oak	203	BB	22-23	3757-3904
19904	single block	1(hook)	49	ash	308	BB	22-23	x
19905	pendant block	9	38	ash	406	BB	19-20	3283-3435
19906	single block	1(hook)	50	ash	357	BB	22-23	3757-3904
19907	single block	1	30	oak	193	BB	22-23	3757-3904
19913	sheave	1	NA	NA	xx	BB	26-27	4370-4525
19919	single block	1	28	oak	181	MS	26-27	4370-4525
19994	single block	1	28	oak	188	BB	22-23	3757-3904
19995	single block	1	30	oak	189	BB	22-23	3757-3904
19999	single block	1	30	ash	218	BB	22-23	3757-3904
20000	lift block	5	27	birch	379	BB	22-23	3757-3904
23885	fiddle block	3	57	oak	697	BB	22	x
18775	fiddle block	3	x	ash	x	BB	22-23	x

Table Appendix.4 (*cont'd*). Table of blocks found on the orlop and their locations.

Blocks Found in the Hold

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
12377	single block	1	34	oak	230	SB	10-11	x
12417	fragment	2	unknown	ash	253	SB	15-21	x
12418	sheave	1	NA	NA	xx	SB	15-21	x
12419	fragment	NA	unknown	oak	178	SB	15-21	x
12420	single block	1	37	oak	222	SB	15-21	x
12425	single block	1	28	ash	148	SB	15-21	x
12426	single block	1	29	oak	180	SB	15-21	x
12427	single block	1	24	ash	174	xx	15-21	x
12440	double block	1	25	oak	172	SB	15-21	x
12697	sheave	1	NA	NA	xx	BB	11-12	x
12698	fragment	NA	unknown	oak	146	BB	11-12	x
13471	fragment	NA	unknown	oak	174	x	x	center drain
13472	fragment	NA	unknown	oak	177	x	x	center drain
13487	fragment	NA	unknown	oak	138	xx	x	x
13541	fragment	NA	unknown	?	175	x	x	center drain
13542	fragment	NA	NA	NA	188	x	x	center drain
14768	fragment	NA	unknown	oak	189	BB	19-21	3297-3601
14895	single block	1	37	ash	260	SB	26	4383
14896	single block	1	35	ash	252	SB	x	4383
14897	single block	1	31	oak	203	SB	26	4383
14898	single block	1	28	oak	193	SB	26	4383
14899	single block	1	unknown	oak	230	SB	26	4383
15101	fragment	NA	unknown	oak	188	BB	19-21	32,97-3601
15251	single block	1	40	ash	252	SB	25	4273
15252	double block	1	32	oak	199	SB	25	4273
15253	double block	1	29	oak	201	SB	25	4273
15254	single block	1	unknown	ash	159	SB	25	4273
15255	double block	1	39	ash	230	SB	26	4273
15256	single block	1	27	oak	180	SB	25	4273
15257	double block	1	36	oak	204	SB	26	4273
15259	single block	1	37	oak	240	SB	25	4273
15280	single block	1	36	ash	273	SB	25	4273
15328	single block	6	43	ash	241	BB	20-21	3453-3601
15374	single block	1	35	oak	248	SB	25	4273
15375	single block	1	29	ash	199	SB	25	4273
15376	double block	1	32	oak	210	SB	26	x
15377	double block	1	29	oak	197	SB	26	4273
15597	single block	1	42	ash	273	SB	x	x
15598	single block	1	29	oak	161	SB	x	x
15711	single block	1	26	oak	200	SB	25-27	4237
15712	single block	1	35	ash	222	SB	25-27	4237
15713	double block	1	35	oak	240	SB	25-27	
15714	single block	8	50	ash	290	SB	25-27	4237
15724	double block	1	31	oak	190	BB	25-27	4237
15725	single block	1	unknown	oak	175	BB	25-27	4237

Table Appendix.5. Table of blocks found in the hold and their locations.

Blocks Found in the Hold

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
15726	single block	1	32	oak	247	BB	25-27	4237
15759	single block	1	30	oak	209	BB	21-22	3768
15760	dead block	3	35	oak	162	BB	21-22	3768
15764	single block	1	34	oak	208	BB	21-22	3768
15826	fragment	NA	unknown	oak	222	BB	21-22	3768
16120	single block	1	25	ash	142	SB	21-22	3768
16388	single block	1	30	oak	198	SB	23-24	4067
16490	single block	1	28	ash	189	SB	20-21	3601
16718	sheave	1	NA	NA	xx	xx	x	x
16735	single block	1	39	ash	236	SB	25	4237
16825	sheave	1	NA	NA	xx	BB	7-8	1446
16844	single block	1	34	oak	240	xx	x	x
17026	double block	1	34	oak	233	MS	6-7	1290
17093	single block	1	39	ash	243	BB	5-6	997-1137
17850	single block	3	unknown	oak	122	SB	8-9	1593

Table Appendix.5 (*cont'd*). Table of blocks found in the hold and their locations.

Blocks Found in the Debris Field Around the Hull

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
00094	sheave	3	NA	NA	xx	BB	x	D
00112	single block (cat)	1(hook)	80	ash	478	BB	x	D
00114	single block	4	45	ash	445	BB	?	Tunnel D
00125	single block	1	32	ash	203	BB	28-30	Tunnel D
00140	single block	1	39	oak	250	SB	28-30	Tunnel D
00141	single block	1	39	ash	244	BB	28-30	Tunnel D
00253	single block	1	32	ash	208	SB	x	near the stern
00303	single block	1	41	oak	245	xx	x	near the stern
00405	dead block	2	16	ash	85	x	x	near the stern
00407	single block	3	19		111	xx	x	near the stern
00688	single block	10	42	ash	306	SB	x	8m
00711	single block	1	31	ash	245	MS	x	2-3
00962	single block	1	46	ash	298	xx	x	near the stern
00991	single block	3	22	ash	140	xx	x	near the stern
01357	sheave	1	NA	NA	xx	SB	x	near the stern
01771	single block	1	38	ash	235	BB	x	4800-5800
02073	single block	1	30	ash	195	BB	48-56	x
06447	single block	1	unknown	ash	159	BB	24-26	x
20244	double crane	5	36	ash	417	xx	x	stem
20310	single block	1	42	ash	292	x	x	stem
20327	single block	7	58	ash	334	x	x	x
20452	double block	1	37	oak	222	x	x	stem
20490	dead block	1	47	ash	203	xx	x	x
20517	single block	1(hook)	90	ash	480	x	x	stem
20526	single block	1(hook)	87	oak	480	xx	x	x
20527	lift block	5	38	ash	425	xx	x	stem
20532	single block	1	33	oak	175	x	x	stem
20707	single block	1	35	ash	218	x	x	near the bow
20708	single block	1	33	ash	203	x	x	near the bow
20709	single block	2	34	ash	256	xx	x	near the bow
20728	fragment	NA	unknown	ash	223	x	x	near the bow
20746	snatch block	11	43	ash	239	SB	x	near the bow
20748	fragment	NA	unknown	ash	227	SB	x	near the bow
20788	sheave	1	NA	NA	xx	x	x	near the bow
20791	single block	1	35	ash	258	x	x	near the bow
20792	single block	1	36	ash	231	x	x	stem
20793	fragment	NA	unknown	ash	216	x	x	stem
20794	double block	1	34	oak	232	x	x	near the bow
20795	fiddle block	3	40	ash	456	x	x	stem
20796	single block	6	60	ash	385	x	x	stem
21351	sheave	1	NA	NA	xx	xx	x	x
21454	lift block	5	34	ash	427	BB	10-15	x
21716	single block	1	32	ash	175	SB	15-25	x
21724	single block	1	38	ash	254	SB	25-35	x
21736	single block	1	33	oak	179	SB	x	x

Table Appendix.6. Table of blocks found in the debris field around the hull and their locations.

Blocks Found in the Debris Field Around the Hull

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)	Side	Beam Number	Distance aft (cm)
21738	single block	2	38	ash	253	SB	x	30-40
21740	single block	1	32	ash	190	SB	30-40	x
21747	sheave	1	NA	NA	xx	SB	30-40	x
21760	single block	1	30	ash	198	SB	35-40	x
23078	single block	6	82	ash	506	x	x	x
23086	single block	2	24	oak	148	xx	x	x
23117	pendant block	9	45	ash	398	xx	x	x
23135	single block	2	23	oak	150	xx	x	x
23137	single block	1	37	ash	249	x	x	x
23148	single block	2	27	ash	174	xx	x	x
23257	dead block	2	19	ash	85	x	x	x
23358	single block	1	43	ash	295	BB	x	10-15
23455	sheet/lift block	6	77	ash	715	BB	x	x
23465	single block	6	73	ash	525	x	9-16	15-25
23466	single block	4	50	ash	490	BB	x	15-25
23498	single block	1	37	ash	232	BB	x	15-25
23499	single block	1	33	ash	232	x	x	15-25
23504	single block	10	38	ash	309	BB	15-25	x
23520	single block	1	35	ash	196	BB	15-25	x
23575	sheave	3	NA	NA	xx	BB	10-15	x
24237	double block	1	32	oak	210	xx	x	x

Table Appendix.6 (*cont'd*). Table of blocks found in the debris field around the hull and their locations.

Blocks with No Find Location Data

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)
14169	sheave and axle	1	NA	ash	123
20624	single block	13	30	ash	190
23136	single block	2	55	ash	398
23140	fiddle block	3	34	ash	447
23692	sheave fragment	3	NA	?	113
20518a	single block	4	60	ash	498
20518b	sheave	1	NA	NA	xx
08246	sheave	1	NA	NA	xx
23084	sheave	1	NA	NA	xx
23145	fragment	NA	unknown	ash	200
24236	single block	1	30	ash	203
34894	axle	NA	NA	NA	xx
B 104	fragment	NA	unknown	ash	143
B 107	sheave	1	NA	NA	xx
B 164	fragment	NA	unknown	oak	169
B 20	sheave	1	NA	NA	xx
B 76	fragment	NA	unknown	oak	194
B 77	fragment	NA	unknown	ash	194
B 93	fragment	NA	unknown	ash	219
B105	sheave	1	NA	NA	xx
BI59	sheave	1	NA	NA	xx
BI62	sheave	1	NA	NA	xx
BI63	sheave	1	NA	NA	xx
NN03	single block	1	33	oak	216
NN05	fragment	NA	unknown	ash	136
NN06	axle	NA	NA	NA	xx
NN07	sheave	1	NA	NA	xx
NN08	single block	14	32	?	202
NN09	single block	2	38	ash	264
NN10	double block	1	30	oak	202
NN11	double block	1	31	oak	205
NN12	single block	1	28	oak	158
NN13	single block	1	36	oak	192
NN14	single block	1	32	oak	205
NN15	fragment	NA	unknown	oak	168
NN16	fragment	NA	unknown	ash	162
NN17	fragment	NA	unknown	ash	127
NN18	fragment	NA	unknown	oak	178
NN19	sheave fragment	3	NA	?	106
NN20	sheave	1	NA	NA	xx
NN21	sheave	1	NA	NA	xx
NN22	sheave fragment	1	NA	ash	107
NN23	sheave fragment	1	NA	ash	109
NN24	sheave	1	NA	NA	xx
NN25	sheave	1	NA	NA	xx
NN26	single block	2	unknown	oak	143

Find Number	Type	Sub-type	Swallow Diameter (mm)	Wood species	Length (mm)
NN27	sheave and axle	1	NA	NA	xx
NN28	sheave	1	NA	NA	xx
NN29	sheave	1	NA	NA	xx
NN30	sheave and axle	1	NA	NA	xx
NN31	sheave	3	NA	NA	xx
NN32	fragment	NA	unknown	?	90
NN33	axle	NA	NA	NA	xx
NN34	fragment	NA	unknown	oak	91
NN35	fragment	NA	unknown	oak	207
NN36	fragment	NA	unknown	?	197
NN37	fragment	NA	unknown	oak	155
NN38	fragment	NA	unknown	ash	327
NN39	fragment	NA	unknown	?	160
NN40	axle	NA	NA	NA	xx
NN41	axle	NA	NA	NA	xx
NN42	axle	NA	NA	NA	xx
NN43	axle	NA	NA	NA	xx
NN44	axle	NA	NA	NA	xx
NN45	axle	NA	NA	NA	xx
NN46	axle	NA	NA	NA	xx
NN47	axle	NA	NA	NA	xx
NN48	axle	NA	NA	NA	xx
NN49	axle	NA	NA	NA	xx
NN50	axle	NA	NA	NA	xx
NN51	sheave	1	NA	NA	xx
NN54	single block	4	55	ash	481
NN55	single block	1	34	oak	196
00406	single block	1	unknown	ash	174
23116	single block	1	41	ash	265
23139	single block	1	34	ash	224
23143	single block	1	38	oak	260
23144	single block	1	38	ash	243
23147	single block	1	33	ash	188
23282	single block	1	28	ash	168
23283	single block	1	38	oak	230
10715	single block	1	33	oak	213
11420	single block	1	unknown	ash	174
26851	axle	NA	NA	NA	xx
NN01	single block	1	30	oak	222

Table Appendix.7. Table of blocks found with no location data available.